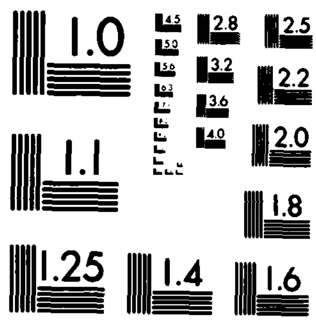
AD-A171 523 DEVELOPMENT OF AN ATMOSPHERIC DISPERSION MODEL FOR HEAVIER-THAN-AIR GAS M..(U) ARKANSAS UNIV FAYETTEVILLE DEPT OF CHEMICAL ENGINEERING J A HAVENS ET AL. MAY 85 1/3

UNCLASSIFIED USCG-D-23-85 DTCG23-80-C-20029 F/G 20/4 NL



'CROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A171 523

Report No. CG-D-23-85

DEVELOPMENT OF AN ATMOSPHERIC DISPERSION MODEL FOR HEAVIER-THAN-AIR GAS MIXTURES

Volume II: Laboratory Calm Air Heavy Gas Dispersion Experiments

JERRY A. HAVENS

THOMAS O. SPICER

FINAL REPORT
MAY 1985

Prepared for:

U.S. Department of Transportation
United States Coast Guard

Office of Research and Development
Washington, D.C. 20593

Technical Report Documentation Page

1. Report No. CG-D-23-85	2. Government Accession No. AD-A171523	3. Recipient's Catalog No.

4. Title and Subtitle

DEVELOPMENT OF AN ATMOSPHERIC DISPERSION MODEL FOR HEAVIER-THAN-AIR GAS MIXTURES
VOLUME II: LABORATORY CALM-AIR HEAVY GAS DISPERSION EXPERIMENTS

5. Report Date

May 1985

6. Performing Organization Code

8. Performing Organization Report No.

Final Report

7. Author(s)

Jerry A. Havens and Thomas O. Spicer

9. Performing Organization Name and Address

Chemical Engineering Department
University of Arkansas
Fayetteville, Arkansas 72701

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

DT-CG-23-80-C-20029

13. Type of Report and Period Covered

Final Report
Sept. 1980-May 1985

12. Sponsoring Agency Name and Address

U.S. Coast Guard
Commandant (G-FCP-22F/TP64)
2100 Second Street, NW
Washington DC 20593

14. Sponsoring Agency Code

15. Supplementary Notes

This volume accompanies: Volume I: Development of an Atmospheric Dispersion Model for Heavier-than-Air Gas Mixtures, and Volume III: DEGADIS Model User's Manual.

16. Abstract

Laboratory experimental instantaneous releases of right circular cylindrical volumes of heavy gas (Freon-12/air) with initial volumes ranging from 0.034 m^3 to 0.531 m^3 and specific gravities ranging from 2.2 to 4.2 are described. Releases with initial height-to-diameter ratios of 0.4, 1.0, and 1.57 are reported. The heavy gas flow field surrounding the release is described by time series of gas concentration at various radial and vertical coordinates with respect to release center. Measurements of the gravity current velocities are determined from time-of-onset of measured gas concentration.

Calm-air instantaneous heavy gas releases are demonstrated to scale with a characteristic length $V_i^{1/3}$, where V_i is the initial volume, and a characteristic time $V_i^{1/6}/\sqrt{g'_o}$, where g'_o is the reduced gravitational acceleration. The scaled laboratory releases predict the gravity-spreading and dilution process occurring during the buoyancy-dominated flow phase of the 2000 m^3 Freon/air instantaneous releases conducted by the British Health and Safety Executive at Thorney Island, UK.

The gravity spread and dilution data are used to validate the buoyancy-dominated flow submodel which is incorporated in DEGADIS, the general purpose heavy gas dispersion model developed for the Coast Guard Hazard Assessment Computer System (HACS).

17. Key Words		18. Distribution Statement
Heavy Gas Dispersion	Density Currents	
Turbulent Mixing	Gravity Currents	
Atmospheric Dispersion	Stratified Flows	
Buoyancy-Driven Flows		

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
		282	

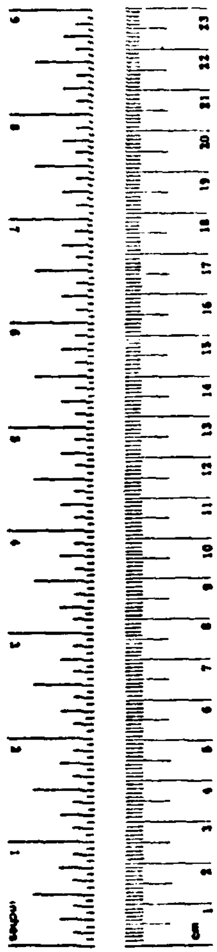
Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

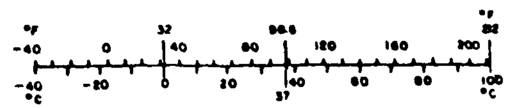


TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

c_E constant in gravity intrusion formula

D cloud diameter, m

g gravitational acceleration, m/s^2

g' reduced gravitational acceleration, $g\Delta'$, m/s^2

H cloud height, m

H^* dimensionless height, H/ℓ

r radial distance, m

R cloud radius, m

R^* dimensionless cloud radius, R/ℓ

R_0^* initial dimensionless cloud radius, R_0/ℓ

t time, s

τ characteristic time, $\sqrt{V_i^{1/3} / g\Delta_i'}$

t^* dimensionless time, t/τ

V_i initial cloud volume, m^3

y gas concentration, mole %

$\bar{y}$ cloud-averaged gas concentration, mole %

z vertical distance, m

<u>Greek Symbols</u>

Δ' reduced density, $(\rho - \rho_a)/\rho_a$

ε frontal entrainment coefficient

ρ cloud density, kg/m^3

ρ_a air density, kg/m^3

ℓ characteristic length, $V_i^{1/3}$, m

<u>Subscripts</u>

i initial or index

SUMMARY

Laboratory experimental instantaneous releases of right circular cylindrical volumes of heavy gas (Freon-12/air) with initial volumes ranging form 0.034 m^3 to 0.531 m^3 and specific gravities ranging from 2.2 to 4.2 are described. Releases with initial height-to-diameter ratios of 0.4, 1.0, and 1.57 are reported. The heavy gas flow field surrounding the release is described by time series of gas concentration at various radial and vertical coordinates with respect to release center. The gas concentration measurements, made using aspirated hot wires, provide high frequency response gas concentration data describing the rapidly slumping, laterally expanding gas cloud. Measurements of the gravity current velocities are determined from time-of-onset of measurable gas concentration.

Calm air, instantaneous heavy gas releases are demonstrated to scale with a characteristic length $V_i^{1/3}$, where V_i is the initial volume, and a characteristic time $V_i^{1/6} / \sqrt{g\Delta_i}$ where $g\Delta_i$ is the reduced gravitational acceleration. The scaled laboratory releases predict the gravity spreading and dilution process occurring during the buoyancy-dominated flow phase of the 2000 m^3 Freon-air instantaneous releases conducted by the British Health and Safety Executive at Thorney Island, UK.

The gravity spread and dilution data are used to validate a buoyancy-dominated-flow submodel which is incorporated in DEGADIS, a general purpose heavy gas dispersion model developed for the Coast Guard Hazard Assessment Computer System (HACS).

I. INTRODUCTION

Mathematical models used to predict the dispersion of heavier-than-air gases (HTAG) released into the atmosphere must provide a description of the gravity-driven flow and attendant mixing (dilution) processes that characterize the initial phases of rapid releases. Since for rapid releases of "compact" gas volumes (i.e. height-to-diameter ratio of order one), the initial gravity-driven flow and mixing processes may result in cloud dilution by one or two orders of magnitude; such processes can be an important determinant of the maximum downwind distance to gas concentrations of the order 1% characteristic of many hydrocarbon fuel lower flammability limits.

This experimental study was sponsored by the Coast Guard as one task area in the development of a general purpose HTAG dispersion model for incorporation in the Coast Guard's Hazard Assessment Computer System (HACS). The experimental program was designed to provide accurate measurement of the gravity spreading velocities and rates of dilution (by mixing with air) of HTAG volumes released instantaneously in calm conditions in order to accurately describe the buoyancy-dominated flow regime. The experiments were made using Freon-12 and Freon-12/air mixtures with initial volumes 0.034 m^3 to 0.53 m^3, different initial cloud densities (Sp. Gr. 2.2 to 4.2), and different height-to-diameter ratios (0.4, 1.0, and 1.57).

Gas concentration measurements were made at a series of radial and vertical positions in the cloud. Both peak gas concentration and cloud average concentration data as a function of time and cloud radial extent from release center are reoorted. Average spreading velocities were measured by inferring time of cloud arrival from gas concentration measurements.

The calm air HTAG release data have been used to validate a gravity spread-dominated regime submodel which is proposed as part of the general purpose HTAG dispersion model DEGADIS developed for the Coast Guard.

II. DESCRIPTION OF CALM-AIR HEAVY GAS DISPERSION EXPERIMENTS

The experimental facility was designed to allow the instantaneous release of up to one cubic meter HTAG onto a smooth solid surface under calm conditions; it consists of a control room and a release containment room (see Figure II.1). The release containment area is isolated from the ventilation and climate control of adjacent rooms. A vertical curtain surrounds the 15.2 m diameter release area to inhibit naturally occurring horizontal air motion during an experiment. The release point is at the center of the measurement area. Gas concentration and velocity measurement stations are movable anywhere in the release area up to a height of one meter. Instrument cables are carried overhead to the control room. The gas for release and calibration is carried from standard high pressure gas cylinders to the point of use through Tygon tubing.

II.1 Experimental Results

Figure II.2 shows a sector of the release area surrounding a 135 liter gas container filled with white smoke marked Freon-12 gas with an initial height-to-diameter ratio one ($(H/D)_i = 1.$). The gas container is a 1/8 inch thick polycarbonate sheet rolled to form a cylinder with vertical exterior support ribs which extend above the cylinder to the end of a rod in a pneumatic cylinder. Figure II.3 shows the release mechanism with a 531 liter container. The release mechanism is rigidly mounted in a framework hung from roof support beams. A solenoid valve operated by the computer control and data acquisition system admits air under the pneumatic cylinder piston for a designated time period, moving the gas container vertically past the gas volume. The container removal time is controlled by the operating pressure of the air supply line and by the length of time the solenoid valve is open; the removal time is measured by timing the passage of a reflective tape marker on the cylinder between light beams projected from optical fibers mounted to the side. Table II.1

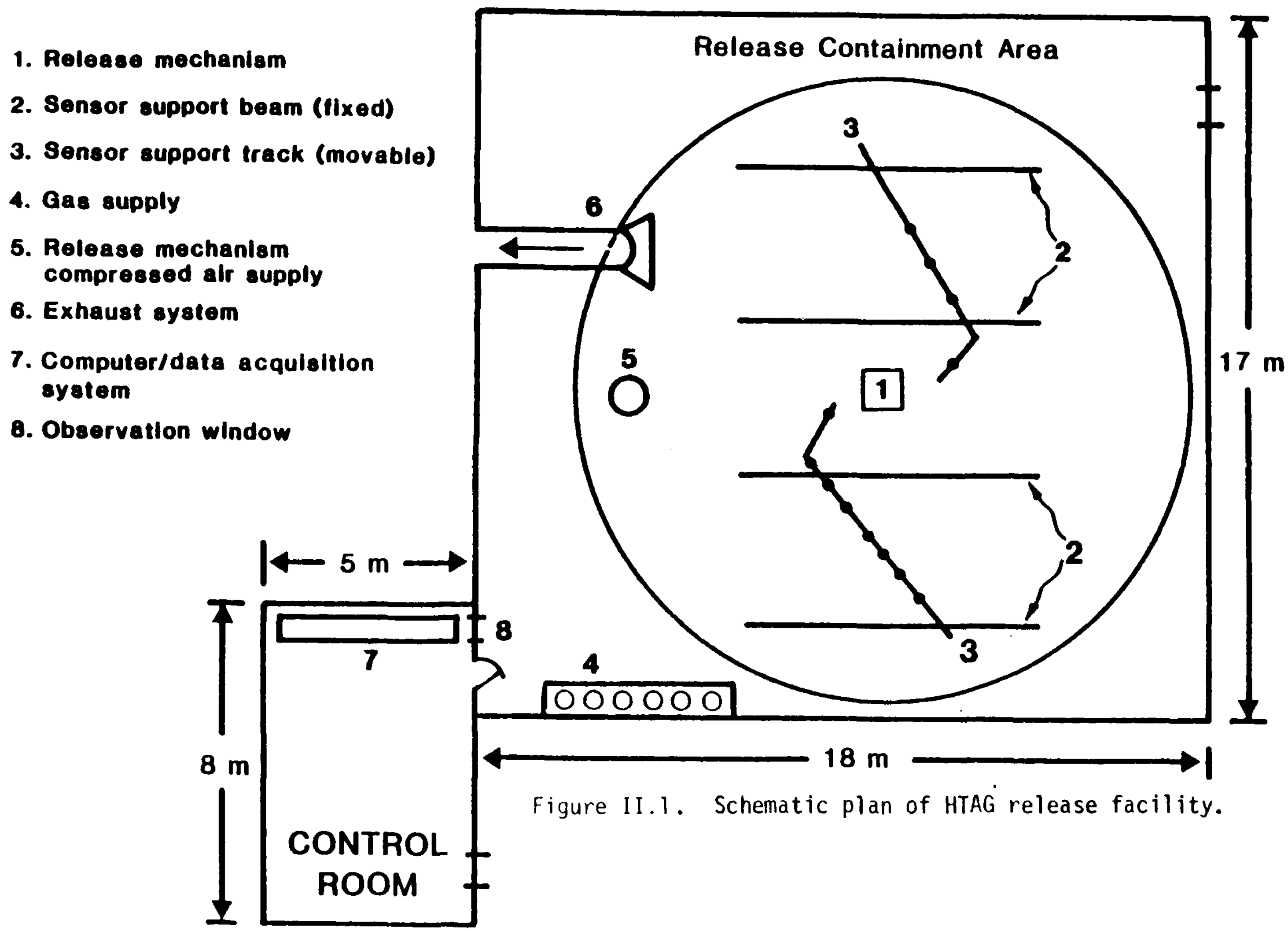
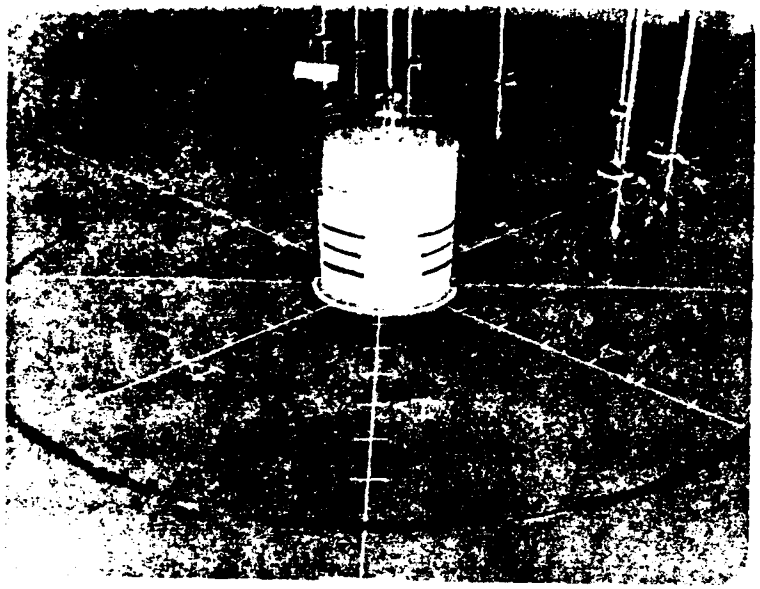


Figure II.1. Schematic plan of HTAG release facility.



[illegible] ... der from [illegible]

Figure [illegible] release mechanism.

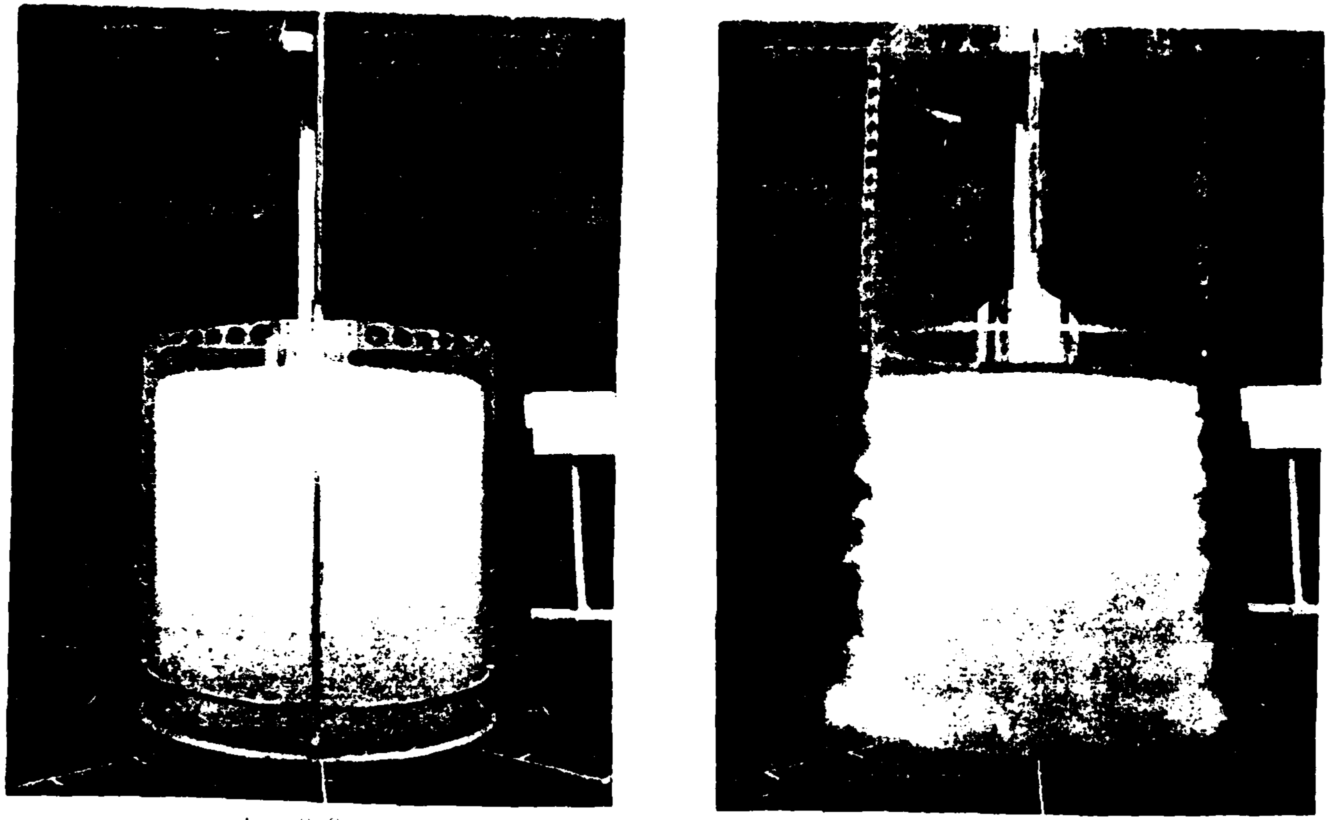
shows typical times required for the gas container to pass the top of the released gas, and its variability in repeat experiments.

TABLE II.1

CONTAINER REMOVAL TIMES

Initial Volume $(H/D)_i = 1.0$	Time to Pass Top of Gas
35 liter	.12 ± .002 sec.
54 liter	.12 ± .002 sec.
135 liter	.24 ± .01 sec.
531 liter	.31 ± .03 sec.

Container removal rates were studied using smoke-marked gas volumes to determine operating conditions required to leave a freestanding, minimally perturbed, cylindrical gas volume after the container had risen above the gas. Figure II.4 shows photographs of a 531 liter container ($(H/D)_i = 1.0$) initially containing smoke-marked CO_2 taken immediately before and 0.31 seconds after initiation of container movement. The second frame indicates that the bottom of the container is past the top of the gas volume 0.31 seconds after its vertical movement began, and the gas is shown to be freestanding with only minimal perturbation. The slight perturbation of the cloud edge which appears as the container clears the gas volume may be induced by vibration of the plastic container wall during its vertical travel, although the local circulatory flows which appear to be beginning at this time would be expected to arise as a result of Kelvin-Helmholtz type instabilities of the density-stratified shear flow at the interface. In any case, variability in the initial condition of the release is assumed negligible in analysis of the subsequent flow process. The variability which does occur in the time series of concentration at a given position in different



t = 0.0 s

t = 0.31 s

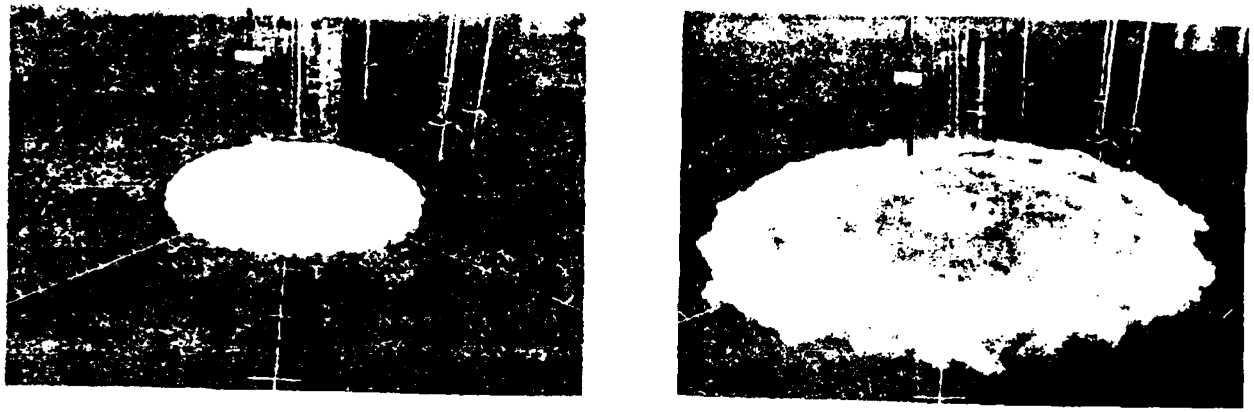
Figure II.4. Free standing gas cylinder initial condition.

experiments is believed to be due to the random nature of the flow itself but may be slightly affected by the impossibility of eliminating the last traces of naturally induced air circulation in the release area and by uncertainty in the gas concentration measurements.

Figure II.5 shows a 135 liter Freon-12 release at two successive times; Figure II.6 shows overhead views of the same release. In Figure II.6, the gas container is just hidden under the square plate which is part of the release mechanism framework. The edge of the spreading gas cloud has advanced to a radial distance of 1.5 m at 0.7 s and 2.0 m at 1.0 s. The radial symmetry of the cloud is clearly indicated. Observations of the cloud's movement beyond the edges of the area photographed confirmed radially symmetric cloud advance to distances at which the peak gas concentration at floor level has decreased to at least 1% of the initial value. The spreading gas rapidly forms a torus or doughnut shape, as observed in previous wind tunnel (Hall, 1982) and field (Picknett, 1978) calm-air and low-wind releases.

II.1.1 Experimental Procedure

The gas container was filled by introducing the test gas through a gas "diffuser" plate, with eight radial outlets to minimize mixing effects due to jetting, at the bottom of the open-topped cylinder. Horizontal overflow slots cut in the container wall determined the gas height when filled. Experiments indicated that gas addition at 10 liters/minute for a period sufficient to add twice the gas container volume resulted in a HTAG interface at the horizontal slots which was very sharp, with the gas concentration below the slots esimtated to be greater than 98% pure gas. During cylinder filling, the gas overflowing through the horizontal slots flowed down the exterior wall of the container and was dispersed by four small (100 CFM) axial flow instrument cooling fans placed at floor level about one cylinder radius away, at 90° angles.



...ure 11... after release

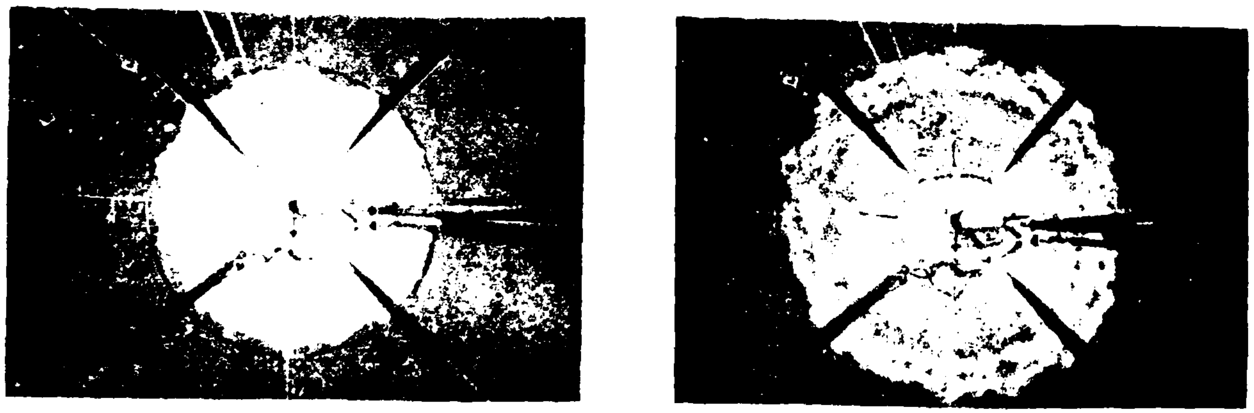


Figure ... after release.

After the cylinder was filled, all personnel moved to the adjacent room housing the data acquisition and experimental control computer system, and the room containing the spill area was sealed. A calming period of ten minutes was observed, then the computer sequenced the actuation of photographic lights and cameras (when used), the raising of the gas container, and the data acquisition.

Generally, experiments were repeated to give three experimental data sets under (intended) identical conditions. Following completion of the releases and the final calibration check (when gas concentration measurements were made), the exhaust fans were turned on to clear the release area.

II.1.2 Gas Concentration Measurements

Figure II.7 shows a sector of the release area with gas sensors mounted on vertical support rods. Sensors are positioned on different radii to avoid interference in the flow caused by other sensors. Figure II.8 is a schematic description of a gas sensor, and Figure II.9 shows a sensor mounted on a support rod. A vacuum pump aspirates gas through a 4 mm diameter sample port fitted with a fibrous filter; the sample flows over a 4 μ wire or 25 μ film mounted on a TSI 1260 anemometer probe, and then through a 400 μ diameter choke. The aspiration rate with the 400 μ choke was approximately 1.5 liters/minute, although some measurements were made with aspiration rates as low as 300 ml/min. The high aspiration rates were used to maximize the resolution of the peak concentrations in the cloud.

The hot wires or films were operated at overheat ratios of 1.32 and 1.16 respectively, corresponding to an operating temperature of about 85°C. This operating condition was determined to give good resolution of the concentration of Freon-12/air mixtures without appreciable deterioration of the sensors experienced in high Freon-12 concentration, high overheat ratio usage. The output of the TSI 1053B anemometers was fed to a reference voltage shifting circuit, through a low pass filter (100 Hz) and amplifier, and input to a

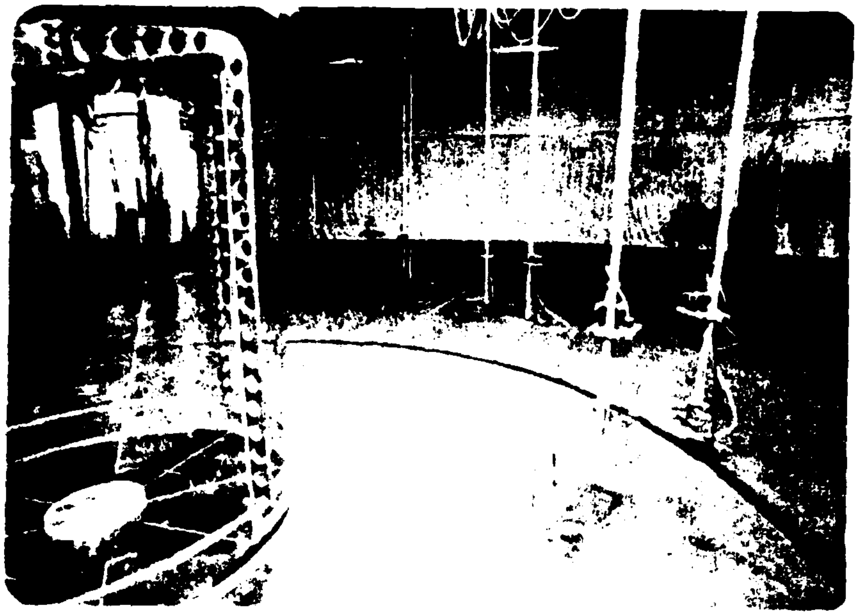


Figure II-7. Gas sensor positions.

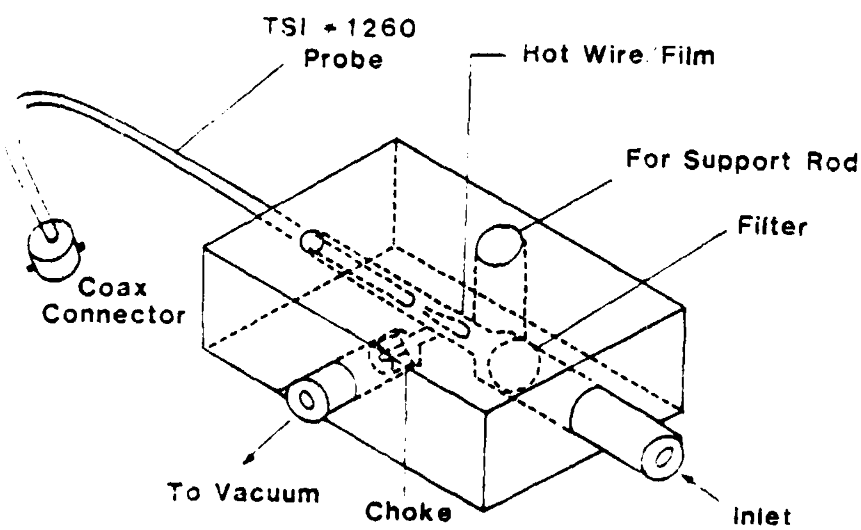


Figure II-8. Schematic diagram of aspirated hot wire gas sensor.

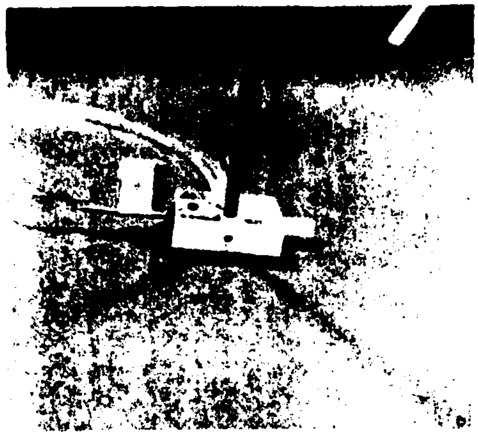


Figure II.9. Gas sensor mounting.

DEC MINC/11-23 computer data acquisition system (Figure II.[illegible]). Gas concentration measurements were typically made at 250 Hz for 50 seconds after release.

Gas calibration mixtures were fed to the gas sensors just before filling the container and again at the end of a series of three identical releases. Clear air readings were also made between releases to correct for sensor drift which may result primarily from a change in air temperature or pressure and secondarily from other factors such as sensor aging and electronic circuitry drift. The gas concentration measurements reported are estimated to be accurate to within about [illegible] of reading in the range 50-100%, [illegible] of reading in the range 25-50%, 10% of reading in the range 5-25%, and 20% of reading in the area of [illegible] concentration, based on analysis of the sensors' characteristics. Primary standardization of the calibration mixtures prepared with rotameters was done by gas chromatography [illegible].

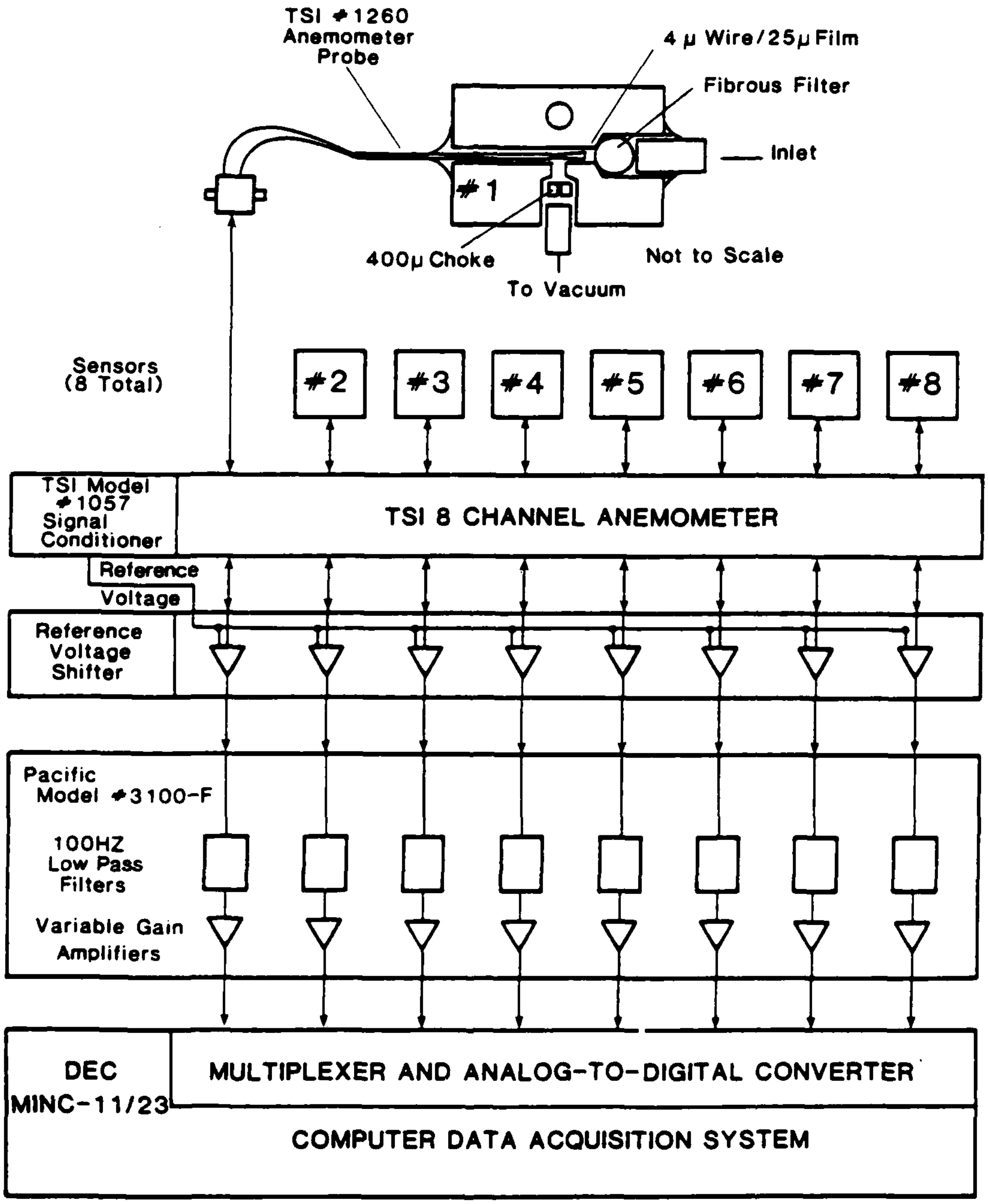


Figure II.10. Aspirated hot wire anemometry concentration measurement system.

III. RESULTS OF CALM AIR HEAVY GAS DISPERSION EXPERIMENTS

Subsequent to a development period during which the experimental procedure was refined, 67 releases of Freon-12 and Freon-12/air mixtures were conducted where gas concentration measurements were made in order to determine air entrainment. The experimental variables studied were: (1) initial gas volume, (2) initial gas density, and (3) initial gas height-to-diameter (aspect) ratio. In most tests, simultaneous gas concentration measurements were made at eight different positions in the HTAG flow field. Table III.1 summarizes the relevant experiments, indicating the radial and vertical coordinates (from ground level spill center) of the concentration measurement positions. In Table III.1, the experiments are grouped by experimental variable: initial volume (V_i), initial specific gravity $(\rho/\rho_a)_i$, and initial height-to-diameter ratio ($(H/D)_i$). Forty-three releases of pure Freon (Sp. Gr. = 4.19) with $(H/D)_i = 1.$ were made, including 3 of 34 liters, 34 of 54 liters, 2 of 135 liters, and 4 of 531 liters initial volume. Seven releases, at three different initial volumes, were made of a Freon-12/air mixture with $(\rho/\rho_a)_i = 2.92$, all with $(H/D)_i = 1$. Five releases, at two different spill volumes, were made of a Freon-12/air mixture with $(\rho/\rho_a)_i = 2.16$, again all with $(H/D)_i = 1$. Finally, three releases of 54 liters pure Freon-12 were made with $(H/D)_i = 0.4$, and nine releases of 54 liters pure Freon-12 were made with $(H/D)_i = 1.57$.

The experimental plan required measurements to be made at different radial and vertical positions in a series of experiments in order to determine radial and vertical concentration profiles. Vertical concentration profile measurements were made to determine cloud height and to provide cloud average concentration as a function of time. Concentration time series measurements for all experiments are given in Appendix A; a summary of time of arrival and peak concentration data is given in Appendix B.

TABLE III.1

RELEASE EXPERIMENT SUMMARY

No.	Run Identification	Initial Volume	Initial Mole Fraction Freon-12	$(H/D)_i$	Sensor Positions R(m)/z(cm) 1	2	3	4	5	6	7	8
Parameter: Initial Volume												
1	817831	34.2	1.0	1.0	1.0/0.6	1.5/0.6	2.0/0.6	2.5/0.6	3.0/0.6	3.0/0.6	4.0/0.6	4.0/0.6
2	817832	34.2	1.0	1.0	1.0/0.6	1.5/0.6	2.0/0.6	2.5/0.6	3.0/0.6	3.5/0.6	4.0/0.6	4.0/0.6
3	817833	34.2	1.0	1.0	1.0/0.6	1.5/0.6	2.0/0.6	2.5/0.6	3.0/0.6	3.5/0.6	4.0/0.6	4.0/0.6
4	815835	54.1	1.0	1.0	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
5	815836	54.1	1.0	1.0	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
6	815837	54.1	1.0	1.0	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
7	B08831	54.1	1.0	1.0	1.5/16.	1.5/0.6	2.9/8.0	2.9/0.6	2.9/16.	4.1/8.0	4.1/0.6	4.1/16.
8	B08832	54.1	1.0	1.0	1.5/16.	1.5/0.6	2.9/8.0	2.9/0.6	2.9/16.	4.1/8.0	4.1/0.6	4.1/16.
9	B09831	54.1	1.0	1.0	1.5/6.0	1.5/0.6	2.9/3.0	2.9/0.6	2.9/6.0	4.1/3.0	4.1/0.6	N/A
10	B09832	54.1	1.0	1.0	1.5/6.0	1.5/0.6	2.9/3.0	2.9/0.6	2.9/6.0	4.1/3.0	4.1/0.6	N/A
11	B11831	54.1	1.0	1.0	1.5/0.6	1.5/4.0	2.9/0.6	2.9/4.0	2.9/11.0	4.1/0.6	4.1/2.0	4.1/4.0
12	B11832	54.1	1.0	1.0	1.5/0.6	1.5/4.0	2.9/0.6	2.9/4.0	2.9/11.0	4.1/0.6	4.1/2.0	4.1/4.0
13	B11833	54.1	1.0	1.0	1.5/0.6	1.5/4.0	2.9/0.6	2.9/4.0	2.9/11.0	4.1/0.6	4.1/2.0	4.1/4.0
14	B15831	54.1	1.0	1.0	1.5/0.6	1.5/2.0	2.2/0.6	2.2/4.0	2.2/8.0	3.5/0.6	3.5/4.0	3.5/8.0
15	B15832	54.1	1.0	1.0	1.5/0.6	1.5/2.0	2.2/0.6	2.2/4.0	2.2/8.0	3.5/0.6	3.5/4.0	3.5/8.0
16	B15833	54.1	1.0	1.0	1.5/0.6	1.5/2.0	2.2/0.6	2.2/4.0	2.2/8.0	3.5/0.6	3.5/4.0	3.5/8.0

TABLE III.1 (continued)

No.	Run Identification	Initial Volume	Initial Mole Fraction Freon-12	$(H/D)_i$	Sensor Positions R(m)/z(cm) 1	2	3	4	5	6	7	8
Parameter: Initial Volume												
17	816831	54.1	1.0	1.0	1.5/0.6	1.5/8.0	2.2/0.6	2.2/6.0	2.2/11.	3.5/0.6	3.5/6.0	3.5/11.
18	816832	54.1	1.0	1.0	1.5/0.6	1.5/8.0	2.2/0.6	2.2/6.0	2.2/11.	3.5/0.6	3.5/6.0	3.5/11.
19	816833	54.1	1.0	1.0	1.5/0.6	1.5/8.0	2.2/0.6	2.2/6.0	2.2/11.	3.5/0.6	3.5/6.0	3.5/11.
20	424841	54.1	1.0	1.0	1.0/0.6	1.0/2.0	1.8/0.6	1.8/2.0	1.8/6.0	2.4/0.6	2.4/2.0	2.4/6.0
21	424842	54.1	1.0	1.0	1.0/0.6	1.0/2.0	1.8/0.6	1.8/2.0	1.8/6.0	2.4/0.6	2.4/2.0	2.4/6.0
22	424843	54.1	1.0	1.0	1.0/0.6	1.0/2.0	1.8/0.6	1.8/2.0	1.8/6.0	2.4/0.6	2.4/2.0	2.4/6.0
23	426841	54.1	1.0	1.0	1.0/0.6	1.0/4.0	1.8/0.6	1.8/4.0	1.8/8.0	2.4/0.6	2.4/4.0	2.4/8.0
24	426842	54.1	1.0	1.0	1.0/0.6	1.0/4.0	1.8/0.6	1.8/4.0	1.8/8.0	2.4/0.6	2.4/4.0	2.4/8.0
25	426843	54.1	1.0	1.0	1.0/0.6	1.0/4.0	1.8/0.6	1.8/4.0	1.8/8.0	2.4/0.6	2.4/4.0	2.4/8.0
26	430842	54.1	1.0	1.0	1.0/0.6	1.0/6.0	2.0/0.6	2.0/2.0	2.0/6.0	2.6/0.6	2.6/2.0	2.6/6.0
27	430843	54.1	1.0	1.0	1.0/0.6	1.0/6.0	2.0/0.6	2.0/2.0	2.0/6.0	2.6/0.6	2.6/2.0	2.6/6.0
28	430844	54.1	1.0	1.0	1.0/0.6	1.0/6.0	2.0/0.6	2.0/2.0	2.0/6.0	2.6/0.6	2.6/2.0	2.6/6.0
29	501842	54.1	1.0	1.0	1.0/0.6	1.0/8.0	2.0/0.6	2.0/4.0	2.0/8.0	2.6/0.6	2.6/4.0	2.6/8.0
30	501843	54.1	1.0	1.0	1.0/0.6	1.0/8.0	2.0/0.6	2.0/4.0	2.0/8.0	2.6/0.6	2.6/4.0	2.6/8.0
31	501844	54.1	1.0	1.0	1.0/0.6	1.0/8.0	2.0/0.6	2.0/4.0	2.0/8.0	2.6/0.6	2.6/4.0	2.6/8.0
32	507843*	54.1	1.0	1.0	1.0/0.6	1.0/0.6	2.0/0.6	2.0/0.6	2.0/6.0	2.6/0.6	2.6/0.6	2.6/6.0
33	507844*	54.1	1.0	1.0	1.0/0.6	1.0/0.6	2.0/0.6	2.0/0.6	2.0/6.0	2.6/0.6	2.6/0.6	2.6/6.0
34	507845*	54.1	1.0	1.0	1.0/0.6	1.0/0.6	2.0/0.6	2.0/0.6	2.0/6.0	2.6/0.6	2.6/0.6	2.6/6.0

*filters removed from positions 2, 3, 4, 6, and 7

TABLE III.1 (continued)

No.	Run Identification	Initial Volume	Initial Mole Fraction Freon-12	$(H/D)_i$	Sensor Positions R(m)/z(cm) 1	2	3	4	5	6	7	8
Parameter: Initial Volume												
35	508841*	54.1	1.0	1.0	1.0/0.6	1.0/0.6	2.0/0.6	2.0/0.6	2.0/6.0	2.6/0.6	2.6/0.6	2.6/6.0
36	508842*	54.1	1.0	1.0	1.0/0.6	1.0/0.6	2.0/0.6	2.0/0.6	2.0/6.0	2.6/0.6	2.6/0.6	2.6/6.0
37	508843*	54.1	1.0	1.0	1.0/0.6	1.0/0.6	2.0/0.6	2.0/0.6	2.0/6.0	2.6/0.6	2.6/0.6	2.6/6.0
*filters removed from positions 1, 4, 5, 7, *and 8*												
38	805831	135	1.0	1.0	1.0/0.6	1.5/0.6	2.3/0.6	3.2/0.6	4.05/0.6	4.7/0.6	5.5/0.6	6.3/0.6
39	805833	135	1.0	1.0	1.0/0.6	1.5/0.6	2.3/0.6	3.2/0.6	4.05/0.6	4.7/0.6	5.5/0.6	6.3/0.6
40	706841*	535	1.0	1.0		1.6/0.6	2.4/0.6	3.2/0.6	4.05/0.6	4.7/0.6	5.5/0.6	6.4/0.6
41	706842*	535	1.0	1.0		1.6/0.6	2.4/0.6	3.2/0.6	4.05/0.6	4.7/0.6	5.5/0.6	6.4/0.6
*filters removed from positions 1, 3, 4, 6, 7, and 8												
42	710841*	535	1.0	1.0	1.0/1.3	1.6/1.3	2.4/1.3	3.2/1.3	4.05/1.3	4.7/1.3	5.5/1.3	6.4/1.3
43	710842*	535	1.0	1.0	1.0/1.3	1.6/1.3	2.4/1.3	3.2/1.3	4.05/1.3	4.7/1.3	5.5/1.3	6.4/1.3

*filters removed from positions 1, 3, 4, 6, 7, and 8

TABLE III.1 (continued)

No.	Run Identification	Initial Volume	Initial Mole Fraction Freon-12	$(H/D)_i$	Sensor Positions R(m)/z(cm)							
					1	2	3	4	5	6	7	8
Parameter: Initial Density												
44	705834	34.2	0.6	1.0	1.0/0.6	1.5/0.6	2.0/0.6	2.5/0.6	3.0/0.6	3.5/0.6	N/A	N/A
45	705835	34.2	0.6	1.0	1.0/0.6	1.5/0.6	2.0/0.6	2.5/0.6	3.0/0.6	3.5/0.6	N/A	N/A
46	705836	34.2	0.6	1.0	1.0/0.6	1.5/0.6	2.0/0.6	2.5/0.6	3.0/0.6	3.5/0.6	N/A	N/A
47	719834	54.1	0.6	1.0	1.0/0.6	1.5/0.6	2.0/0.6	2.5/0.6	3.0/0.6	3.5/0.6	4.0/0.6	N/A
48	719835	54.1	0.6	1.0	1.0/0.6	1.5/0.6	2.0/0.6	2.5/0.6	3.0/0.6	3.5/0.6	4.0/0.6	N/A
49	728831	34.2	0.364	1.0	1.0/0.6	1.5/0.6	2.0/0.6	N/A	3.0/0.6	3.5/0.6	4.0/0.6	4.5/0.6
50	728832	34.2	0.364	1.0	1.0/0.6	1.5/0.6	2.0/0.6	N/A	3.0/0.6	3.5/0.6	4.0/0.6	4.5/0.6
51	802831	135	0.6	1.0	1.0/0.6	1.5/0.6	2.3/0.6	3.2/0.6	4.05/0.6	4.7/0.6	5.5/0.6	6.3/0.6
52	802832	135	0.6	1.0	1.0/0.6	1.5/0.6	2.3/0.6	3.2/0.6	4.05/0.6	4.7/0.6	5.5/0.6	6.3/0.6
53	807831	135	0.364	1.0	1.0/0.6	1.5/0.6	2.3/0.6	3.2/0.6	4.05/0.6	4.7/0.6	5.5/0.6	6.3/0.6
54	807832	135	0.364	1.0	1.0/0.6	1.5/0.6	2.3/0.6	3.2/0.6	4.05/0.6	4.7/0.6	5.5/0.6	6.3/0.6
55	807833	135	0.364	1.0	1.0/0.6	1.5/0.6	2.3/0.6	3.2/0.6	4.05/0.6	4.7/0.6	5.5/0.6	6.3/0.6

TABLE III.1 (continued)

No.	Run Identification	Initial Volume	Initial Mole Fraction Freon-12	$(H/D)_i$	Sensor Positions R(m)/z(cm) 1	2	3	4	5	6	7	8
Parameter: Initial Height-to-Diameter Ratio												
56	808831	54.1	1.0	.4	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
57	808832	54.1	1.0	.4	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
58	808833	54.1	1.0	.4	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
59	809831	54.1	1.0	1.57	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
60	809832	54.1	1.0	1.57	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
61	809833	54.1	1.0	1.57	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
62	811831	54.1	1.0	1.57	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
63	811832	54.1	1.0	1.57	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
64	811833	54.1	1.0	1.57	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
65	815831	54.1	1.0	1.57	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
66	815832	54.1	1.0	1.57	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6
67	815833	54.1	1.0	1.57	1.0/0.6	1.5/0.6	2.2/0.6	2.9/0.6	3.5/0.6	4.1/0.6	4.7/0.6	5.3/0.6

III.1 Cloud Extent

Figure III.1 shows the nondimensional cloud radial extent determined from the onset of measured concentration as a function of the nondimensional time $t^* = t / [V_i^{1/3} / g\Delta_i']^{1/2}$ measured from the start of gas container removal for all of the experiments reported. The DEGADIS source model-predicted radial extent as a function of time is shown by the solid line. For the range of data plotted, the predicted radial extent is essentially independent of aspect ratio $(H/D)_i$ for the ratios tested. The variation of observed cloud radial extent for earlier times can be decreased if the radial extent is expressed as $R^* - R_0^*$.

If the gravity intrusion formula is integrated for a right circular cylinder of gas, the extent of the radially spreading cloud expressed as $R^{*2} - R_0^{*2}$ would be proportional to t^* and the proportionality constant would be $2\ C_E / \sqrt{\pi}$; expressed with logarithms,

$$\log (R^{*2} - R_0^{*2}) = \log t^* + \log (2\ C_E / \sqrt{\pi})$$

Figure III.2 shows that the experimental data reflect this functionality (dashed line with slope = 1.0) after the initial acceleration of the gas cloud from rest. The intercept ($t^* = 1.$) gives $C_E = 1.15$. It should be noted that the predicted radial extent of the cloud for these releases is very insensitive to the value of C_E, but the value of C_E strongly affects the entrainment rate and therefore the value of ε. For $C_E = 1.15$, ε has been determined to be 0.59.

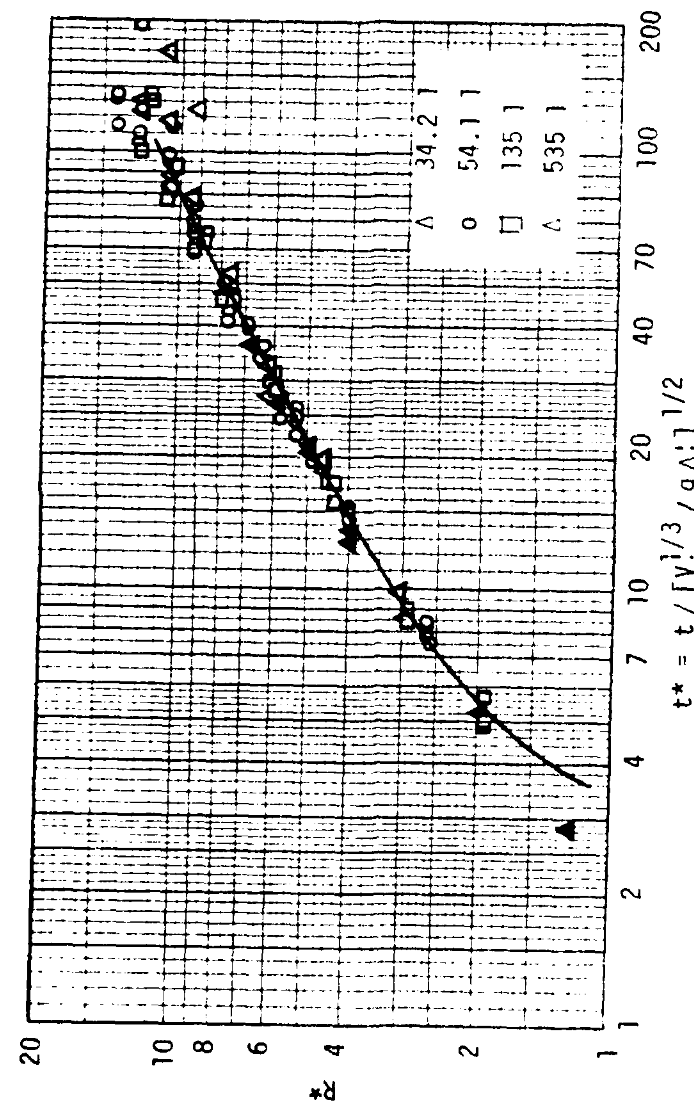


Figure III.1. Nondimensional cloud radial extent vs. time.

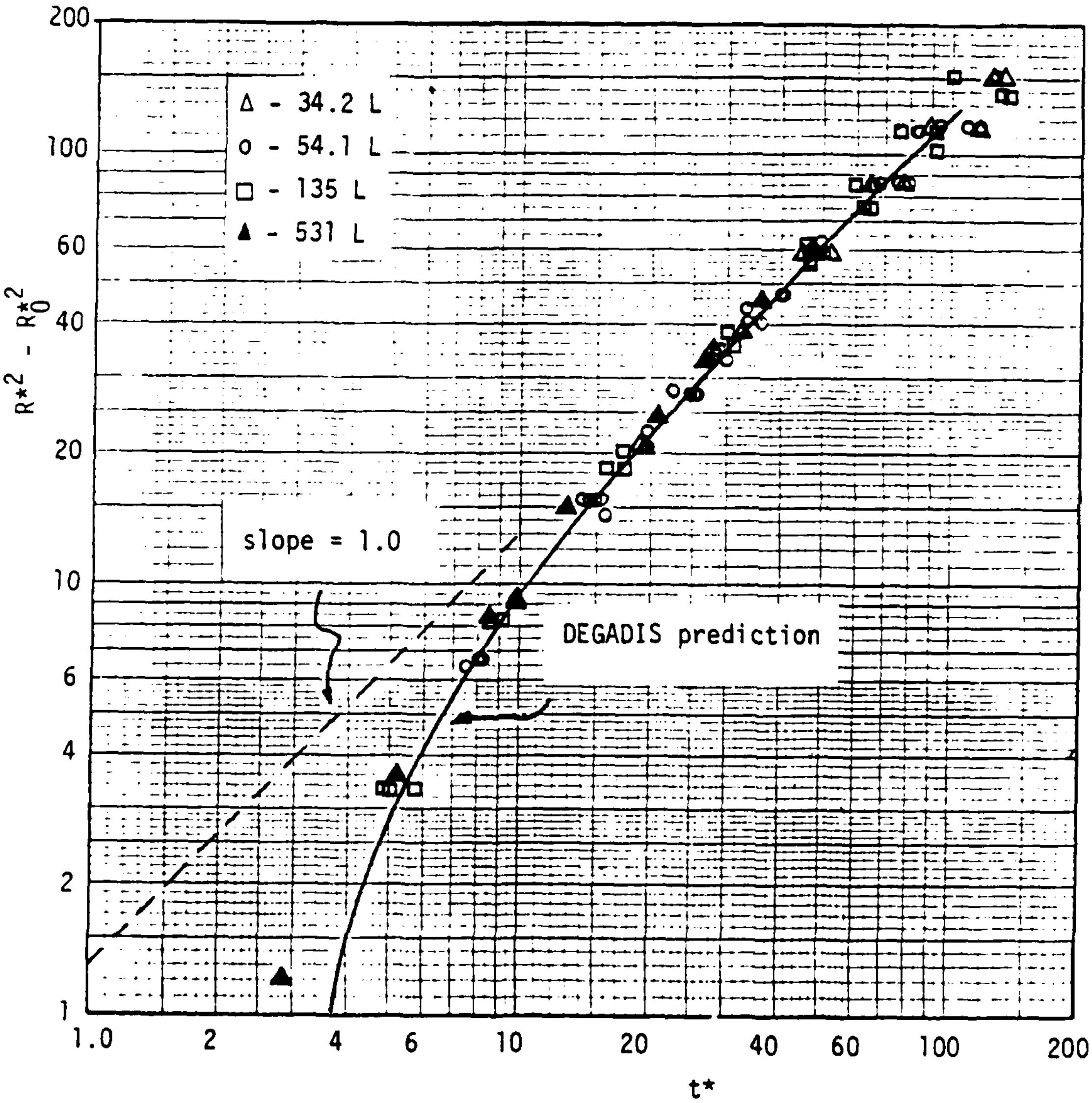


Figure III.2. Predicted and observed nondimensional cloud radial extent vs. time.

III.2 Concentration Measurements

Analysis of the concentration measurements has been directed to the following points considered most relevant to the use of these data in the formulation of the DEGADIS model:

- -- verification of scaling laws
- -- determination of peak gas concentration decrease with distance from spill center
- -- determination of effects of initial density and height-to-diameter ratio
- -- determination of average cloud concentration as a function of time and cloud extent.

III.2.1 Effect of Initial Volume

Calm air releases of cubic volumes of HTAG (Hall, 1982) should be nondimensionalized with a characteristic length scale $\ell = V_i^{1/3}$ and a characteristic time scale $\tau = V_i^{1/6} / \sqrt{g\Delta_i'}$ (Hall, 1983). Figure III.3 shows the maximum (peak) gas concentration measured at various radial distances from release center for all (45) of the pure Freon-12, $(H/D)_i = 1.0$, releases summarized in Table III.1. The measurements of gas concentration are for a 0.6 cm height for the 34, 54, and 135 liter releases ($H^* = 0.0185$, 0.0158, and 0.0117, respectively) and 1.3 cm height for the 531 liter release ($H^* = 0.0185$). All of the gas concentration data were digitized at 250 Hz, and the maximum gas concentrations were obtained from a sliding three point average of the digitized sample points. The peak measured concentrations collapse to the same curve when plotted against the radial position nondimensionalized by the scale length $V_i^{1/3}$.

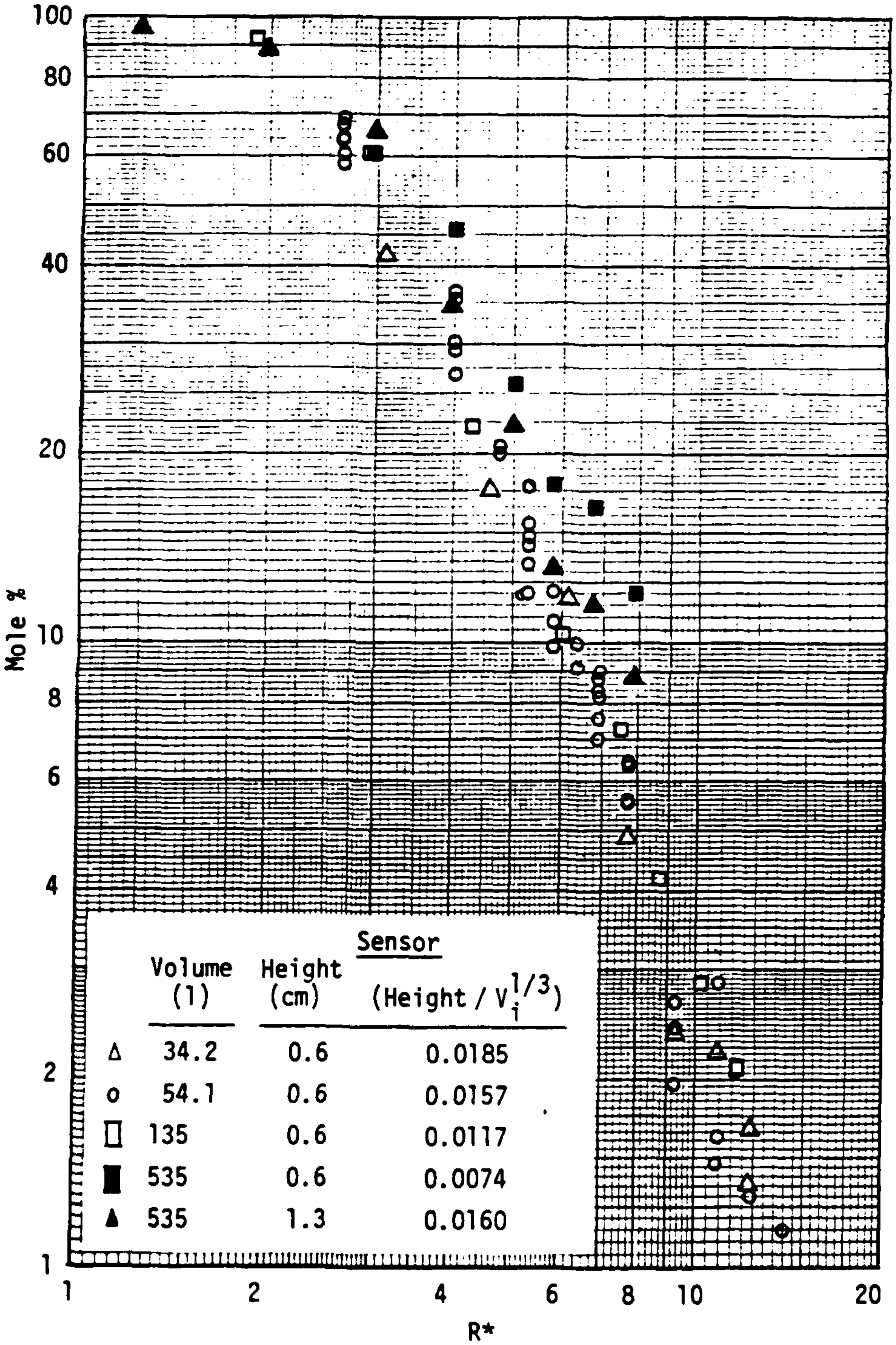


Figure III.3. Peak concentration vs. distance from release center--Freon-12 $(\rho/\rho_a)_i = 4.19$, $(H/D)_i = 1.0$.

III.2.2 Effect of Initial Density

Figure III.4 shows the peak measured gas concentrations vs. the nondimensionalized distance from release center, R*, for releases with $(H/D)_i$ = 1. and specific gravities of 2.16 and 2.92. These specific gravities are for Freon-12/air mixtures of 36% and 60% respectively.

Comparison of Figures III.3 and III.4 indicates the same peak gas concentration decay with nondimensionalized distance from release center for the releases with $(\rho/\rho_a)_i$ varied from 2.16 to 4.19.

III.2.3 Effect of Initial Height-to-Diameter Ratio

Figure III.5 shows the peak measured gas concentration vs. the nondimensionalized distance R* for releases of pure Freon-12 with $(H/D)_i$ of 0.4, 1.0, and 1.57. The data are for 54 liter releases with initial heights 22 cm, 41 cm, and 55 cm, respectively. Although there might be a trend to higher concentrations at the same distance with small $(H/D)_i$, the effect is certainly not pronounced in this $(H/D)_i$ range. Furthermore, comparison of these data must be made in the light of greater uncertainty (i.e., in terms of experimental repeatability) for the $(H/D)_i$ releases. The low releases spread more slowly, and the maintenance of the radial symmetry of the release out to large radii is more affected by the presence of small air currents. However, the data do indicate that for $(H/D)_i$ from 0.4 to 1.57, the dilution mechanism is essentially the same.

Figure III.6 shows the same peak measured gas concentration from Figure III.5 expressed as a function of the nondimensional distance $R^* - R^*_0$ in order to more accurately scale the data for earlier experimental times.

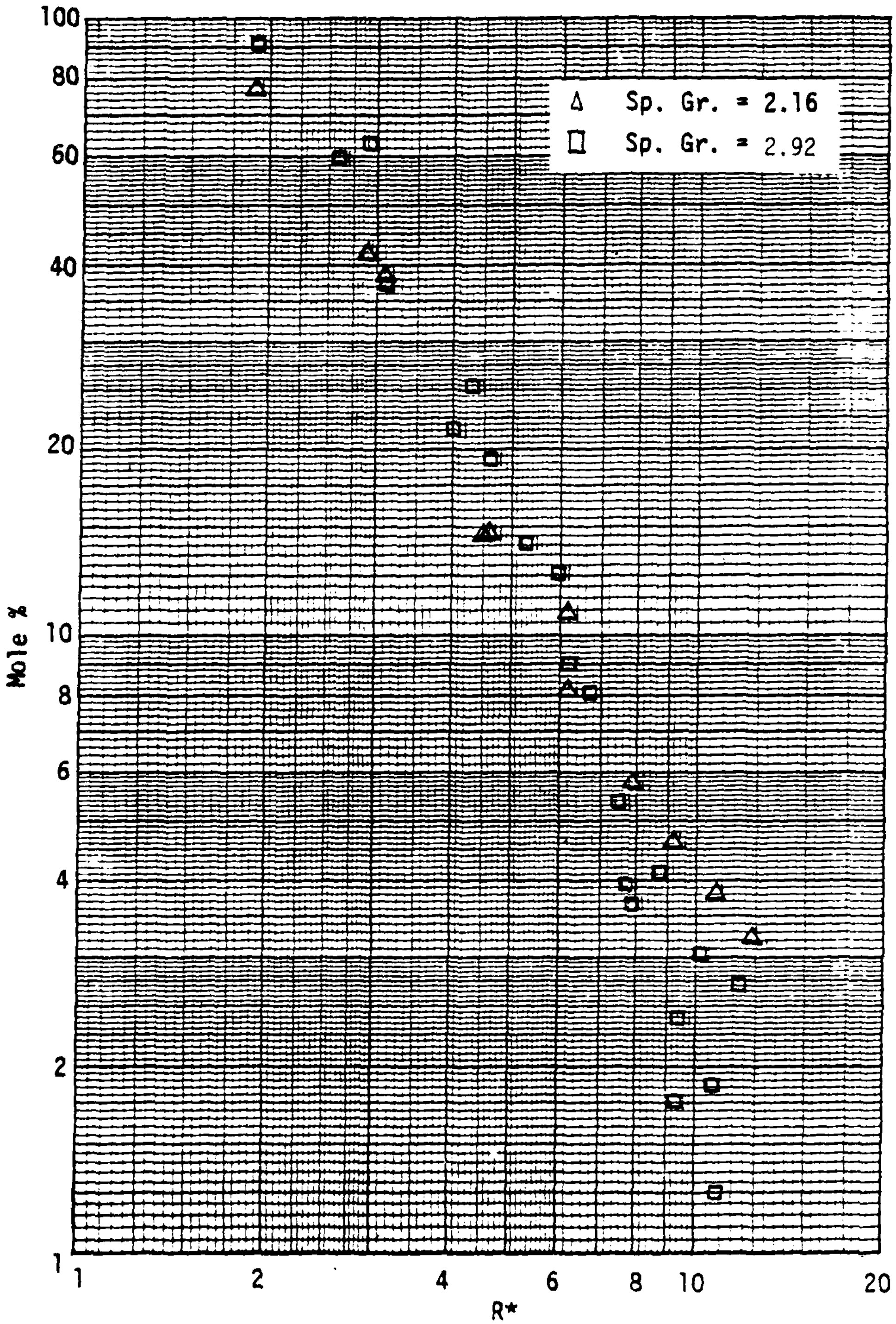


Figure III.4. Peak concentration vs. distance from release center--Freon-12/air mixtures, $(H/D)_i = 1.0$.

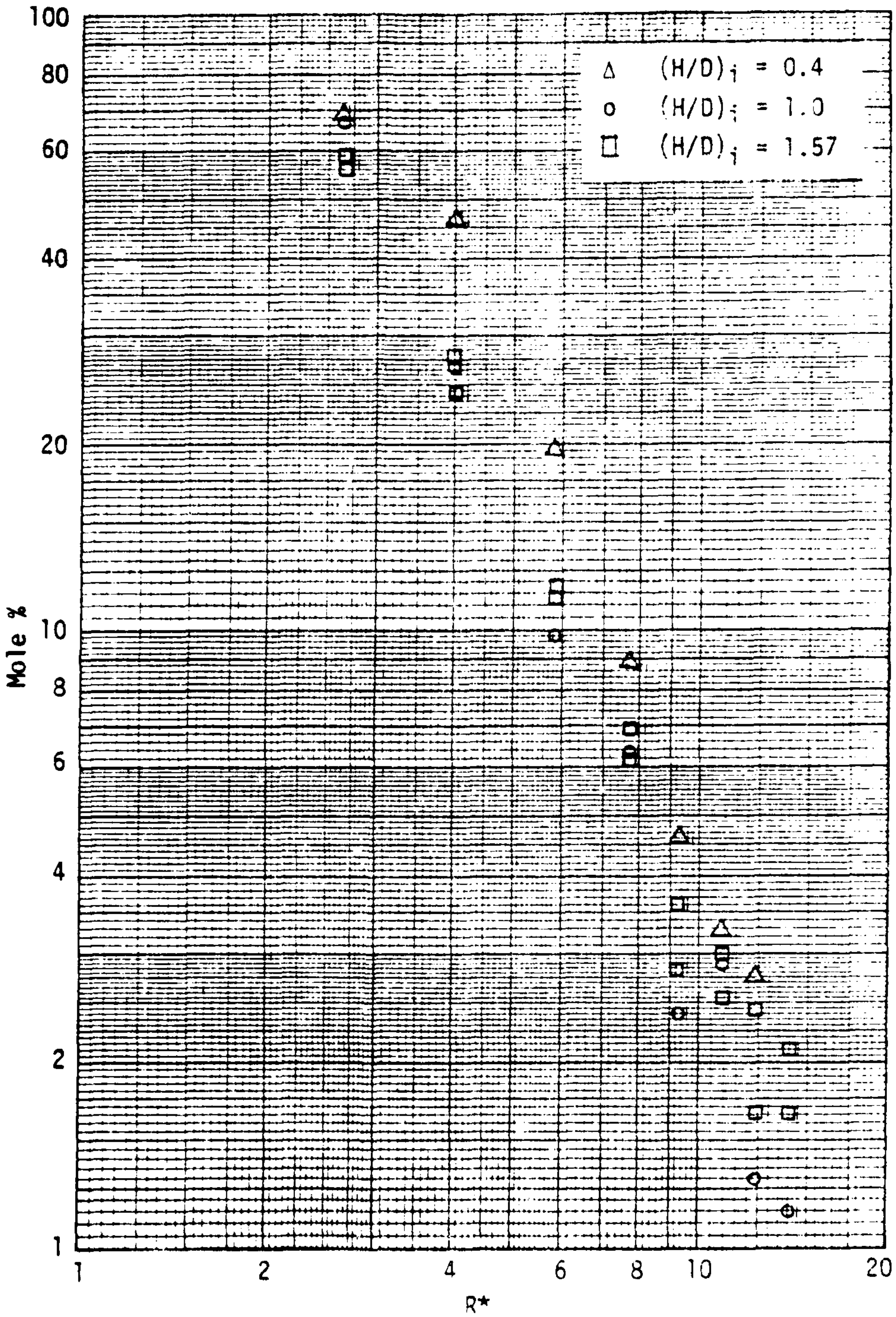


Figure III.5. Peak concentration vs. distance from release center--Freon-12, $(\rho/\rho_a)_i$ = 4.19.

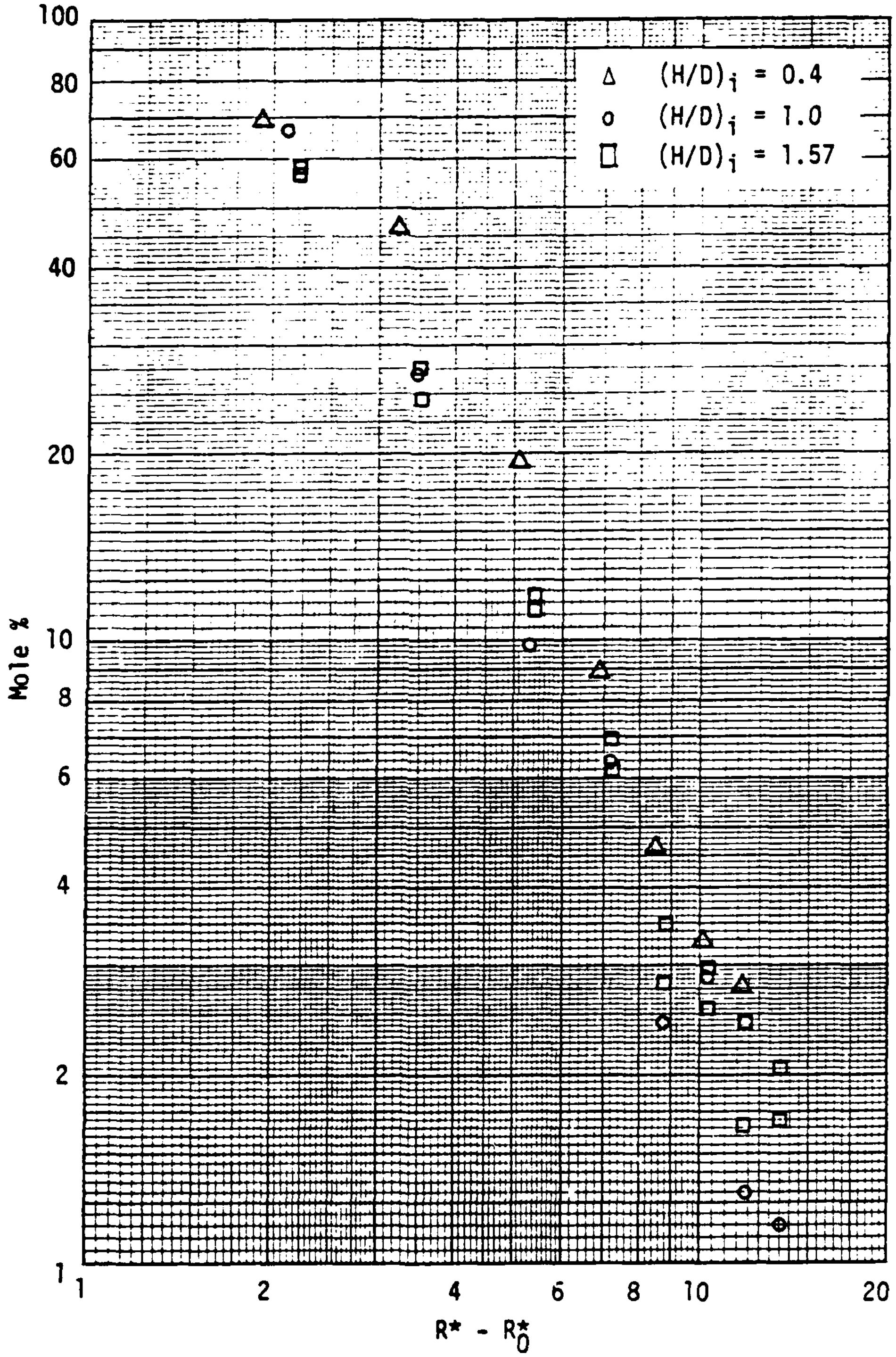


Figure III.6. Peak concentration vs. distance from release center--Freon-12, $(\rho/\rho_a)_i = 4.19$.

III.3 Comparison with Field Scale Experiments

Figure III.7 shows maximum measured concentrations taken from the laboratory calm-air HTAG experiments as a function of radial extent. The distance from release center has been nondimensionalized by the characteristic length $V_i^{1/3}$. Figure III.7 also shows peak concentration measurements vs. the nondimensionalized distance from release center for the Thorney Island Trials 7 through 16 (HSE, 1983). The cloud dispersion process in the Thorney Island (2000 m^3) instantaneous releases is initiated by a rapid gravity-driven flow phase during which the gas flow field is relatively unaffected by the wind (Spicer and Havens, 1985). During this time period, which extends to times at which the cloud concentration has decreased to well below 10%, the laboratory experimental results (for 54-530 liter volumes) scale accurately to the 2000 m^3 releases of Thorney Island, representing a characteristic length scale factor of about 50.

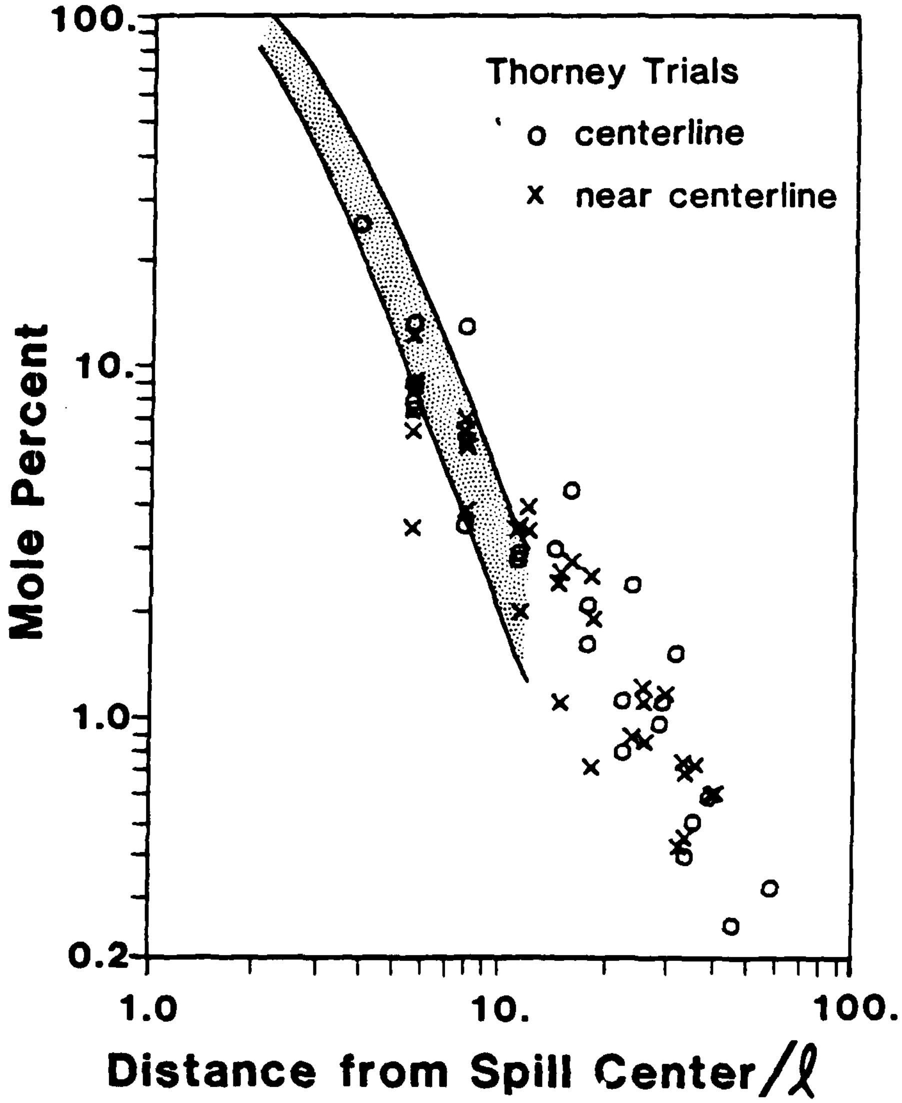


Figure III.7. Laboratory and Thorney Island Trial maximum concentration measurements vs. distance.

III.4 Average Concentration

An extensive series of 54 liter Freon-12 releases, with $(H/D)_i = 1.$ were made to determine the gas concentration time series as a function of radial and vertical position relative to the release center. For several successive times following the release, the concentration data were volume averaged by integrating the radial and vertical concentration distributions in the cloud (Appendix C).

The cloud average concentration vs. radial extent (or time) is useful for verification of box model simulations of the cloud dilution process. Figure III.8 shows the cloud concentration decay with distance from release center (nondimensionalized) predicted using the DEGADIS source model. The predicted average cloud concentration decay with radius is in good agreement with the cloud average concentration decay with distance determined by volume averaging the radial and vertical concentrations.

Figure III.9 shows the same information as Figure III.8 plotted as a function of time. With this change, a direct comparison of the peak and average concentrations can be made. For this type of release, the ratio of the peak-to-average concentration is not strictly constant but is a function of concentration level. However for most approximations, it appears that a peak-to-ensemble-average ratio of 2.0 to 2.5 appears justified.

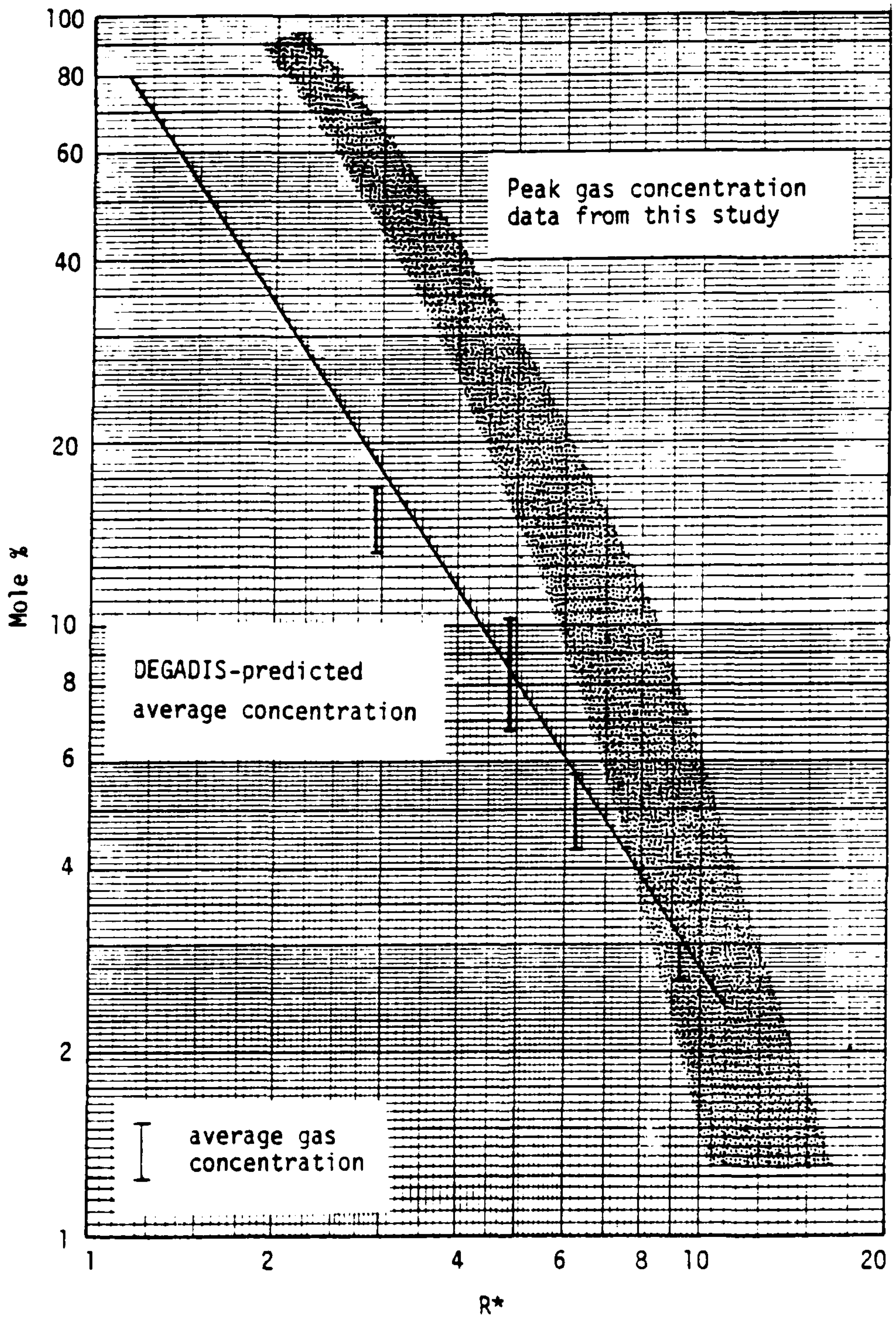


Figure III.8. Peak and average concentration decay with radial distance compared with predicted cloud average concentration.

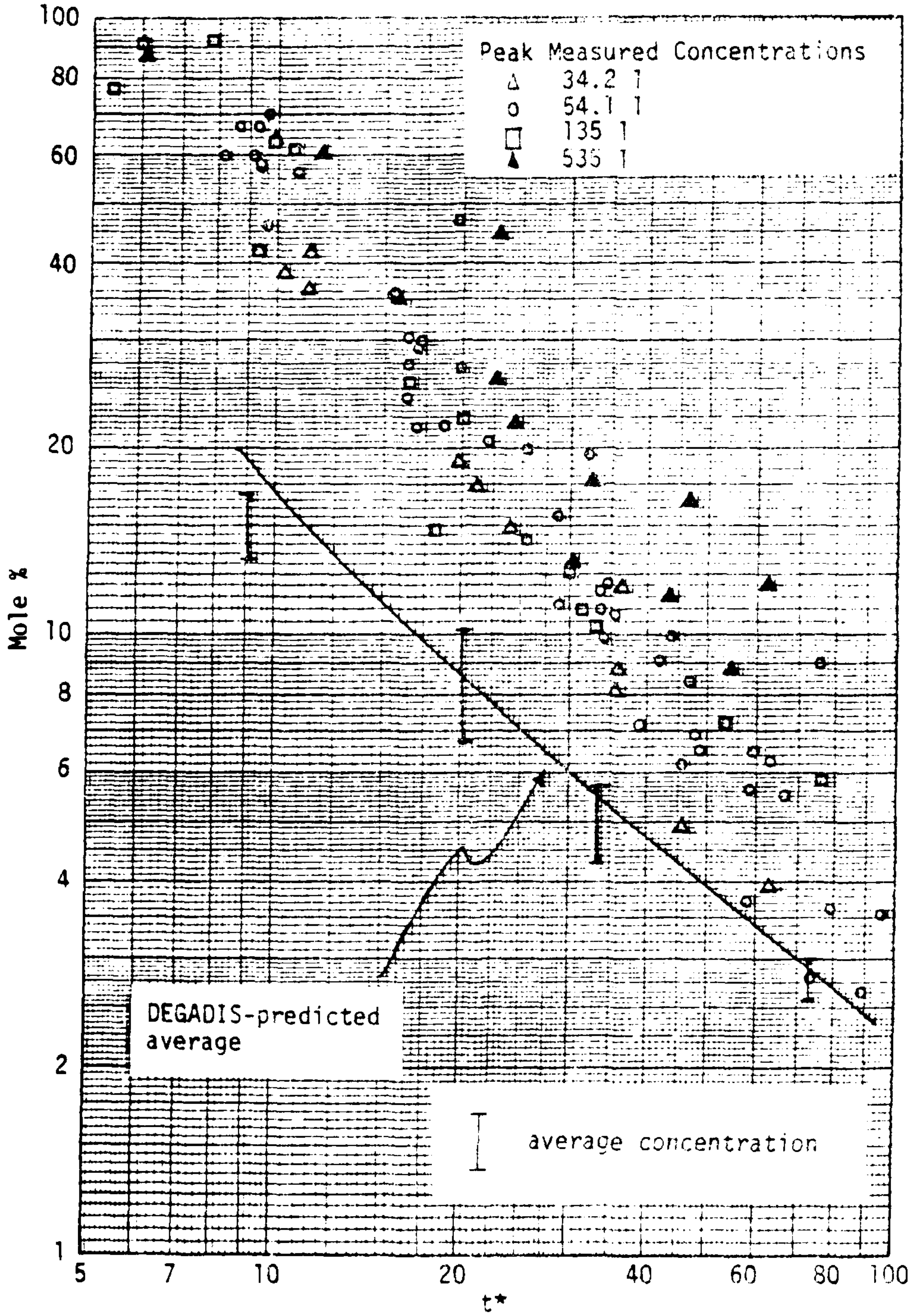


Figure III.9. Peak and average concentration decay with time.

IV. CONCLUSIONS

Laboratory, instantaneous releases of Freon/air mixtures in calm air have been conducted to determine the gravity-spreading velocities and rates of dilution with air which characterize such releases.

Peak gas concentration decay with distance from the release center and cloud spreading velocity are demonstrated to scale with theoretically predicted length and velocity scales over the range of release sizes studied (54 liters to 531 liters), and the results are consistent with measurements made during the gravity-dominated flow regime of the 2000 m^3 Thorney Island Heavy Gas Trials.

Peak gas concentration decay with distance from the release center shows essentially the same pattern for releases with initial specific gravity ranging from 2.2 to 4.2 and initial volume height-to-diameter ratios varying from 0.4 to 1.57.

The gas concentration development with time at a number of radial and vertical positions relative to the release center has been determined for 54 liter, H/D = 1.0 Freon-12 releases. The data have been analyzed to provide cloud average concentration as a function of time and cloud radial extent. The average cloud concentration data have been used to validate a buoyancy-dominated regime submodel similar to that proposed by van Ulden (1983). The buoyancy-dominated regime submodel is incorporated in DEGADIS, the general purpose heavy gas dispersion model developed for the Coast Guard Hazard Assessment Computer System.

V. REFERENCES

Hall, D. J. et al., "A Wind Tunnel Model of the Porton Dense Gas Spill Field Trials," LR 394 (AP), Warren Spring Laboratory, Department of Industry, Stevenage, UK, 1982.

HSE--British Health and Safety Executive, Research and Laboratory Services Division, Red Hill, Sheffield, UK--Heavy Gas Dispersion Trials, Thorney Island 1982-83, Data Digests.

Picknett, R. G., Field Experiments on the Behavior of Dense Clouds, CDE Report PTN, IL 1154/78/1, Porton Down, UK, September 1978.

Spicer, T. O. and J. A. Havens, "Modeling the Phase I Thorney Island Experiments," Symposium on the Thorney Island Heavy Gas Trials, sponsored by the British Health and Safety Executive, Sheffield, UK, April, 1984.

van Ulden, A. P., "A New Bulk Model for Dense Gas Dispersion: Two-Dimensional Spread in Still Air," I.U.T.A.M. Symposium on Atmospheric Dispersion of Heavy Gases and Small Particles, Delft University of Technology, The Netherlands, August 29-September 2, 1983.

APPENDIX A

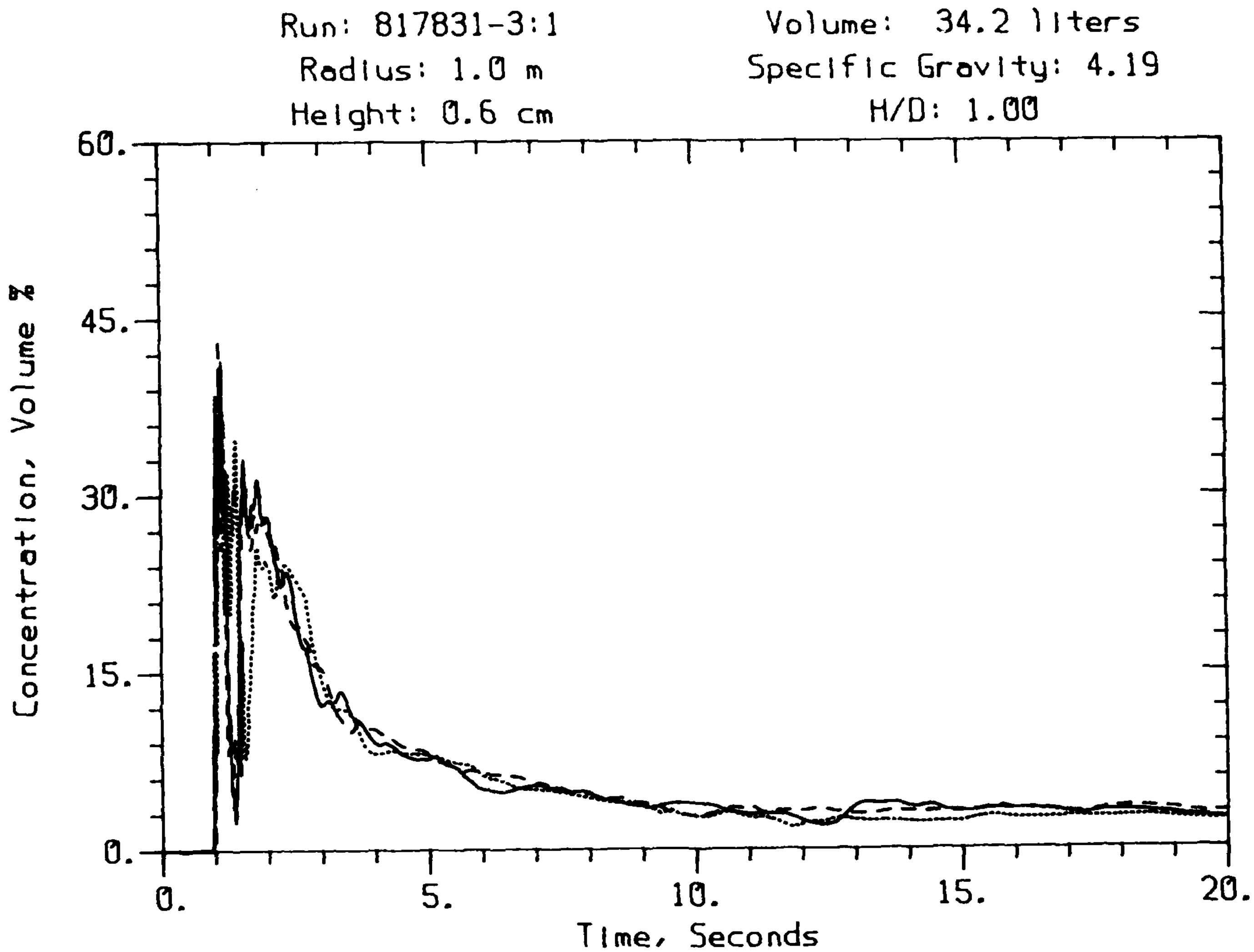
GAS CONCENTRATION MEASUREMENTS

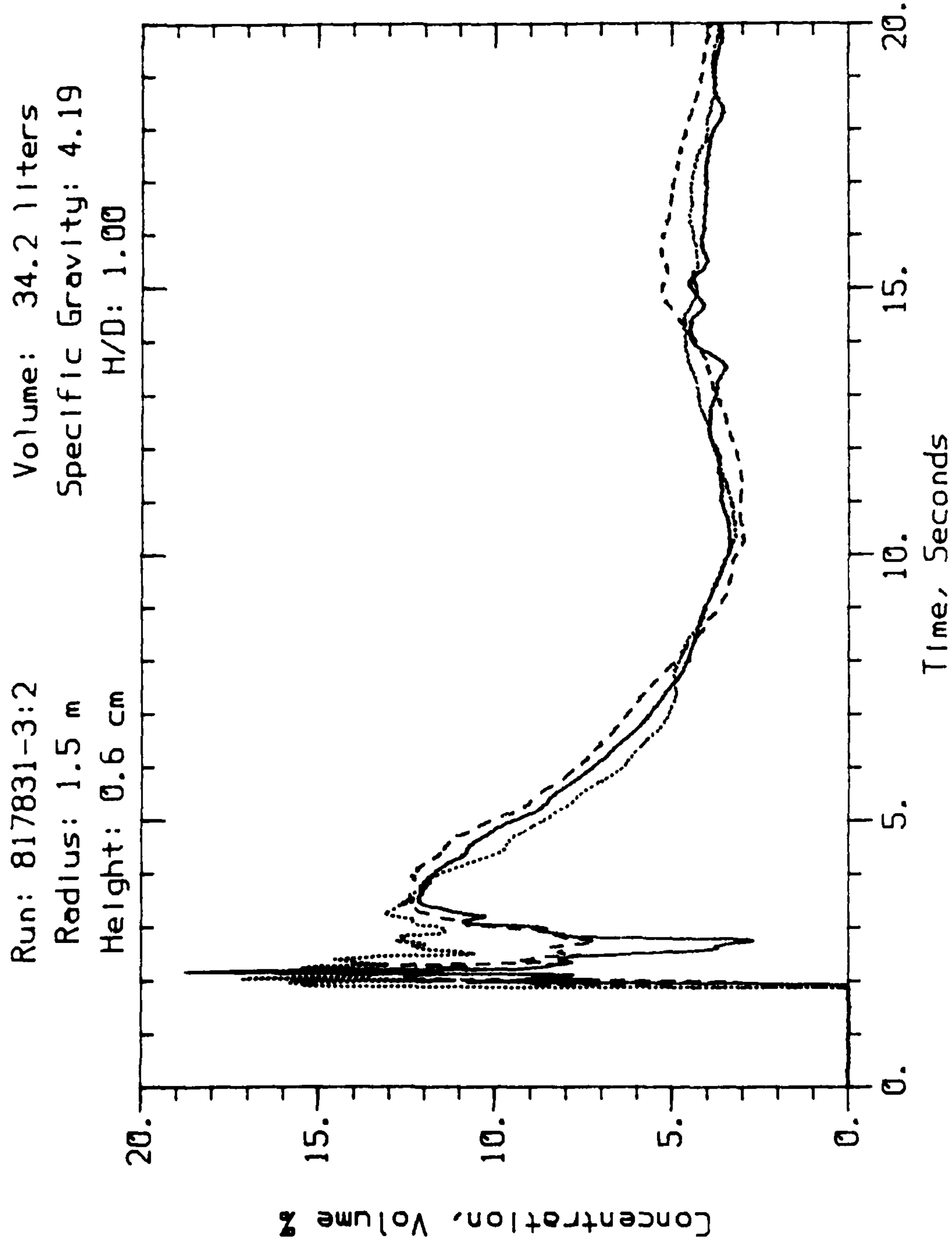
The gas concentration measurements for the experiments summarized in Table III.1 follow. Repeat measurements are plotted together (i.e. Run 817831-3 designates 3 experiments). The experiment run identification number is followed by the designated sensor position number from Table III.1 (i.e. 871831-3:5 designates 3 experiments at position 5 (R = 3.0 m, H = 0.6 cm).

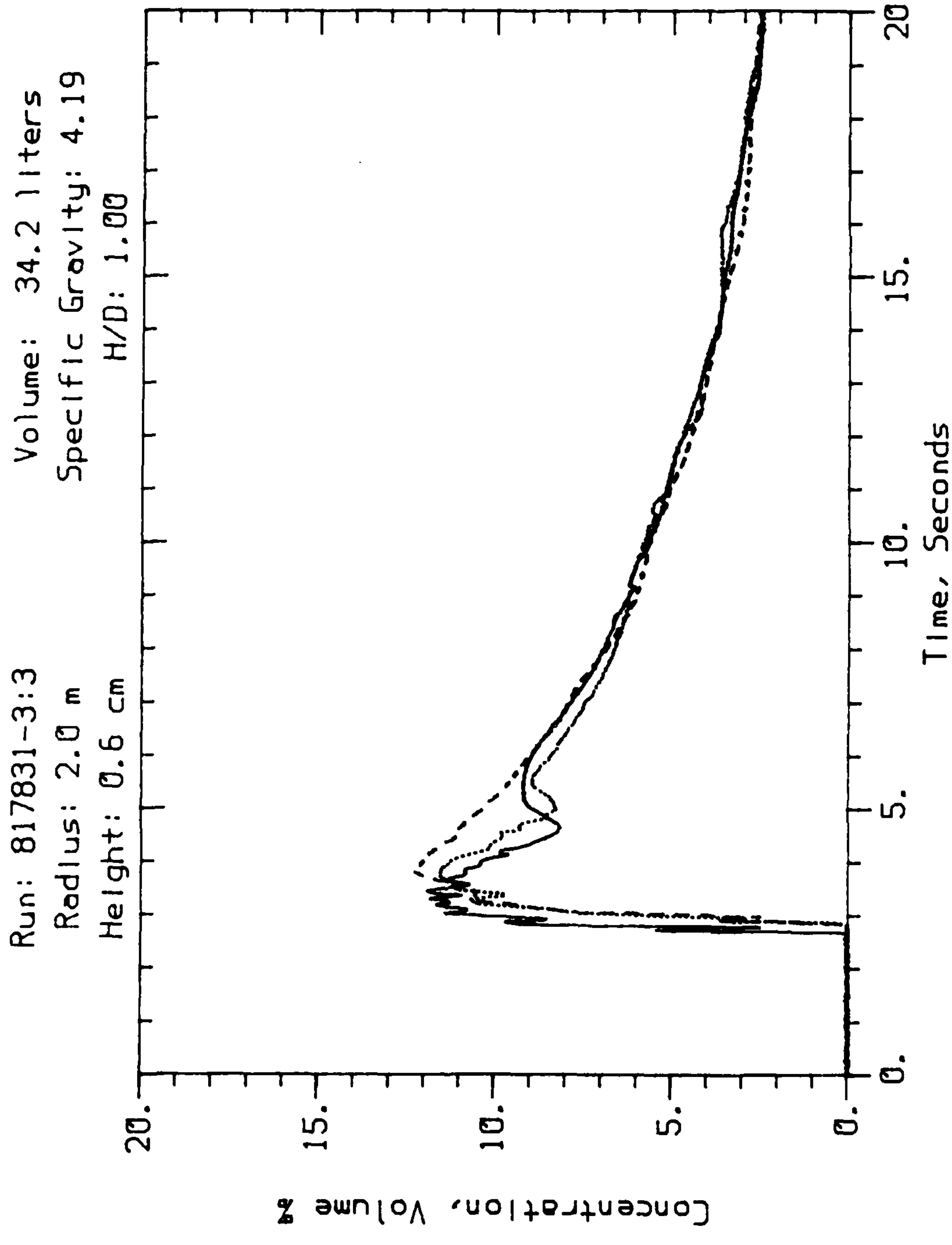
Repeat runs between two calibrations are plotted as follows:

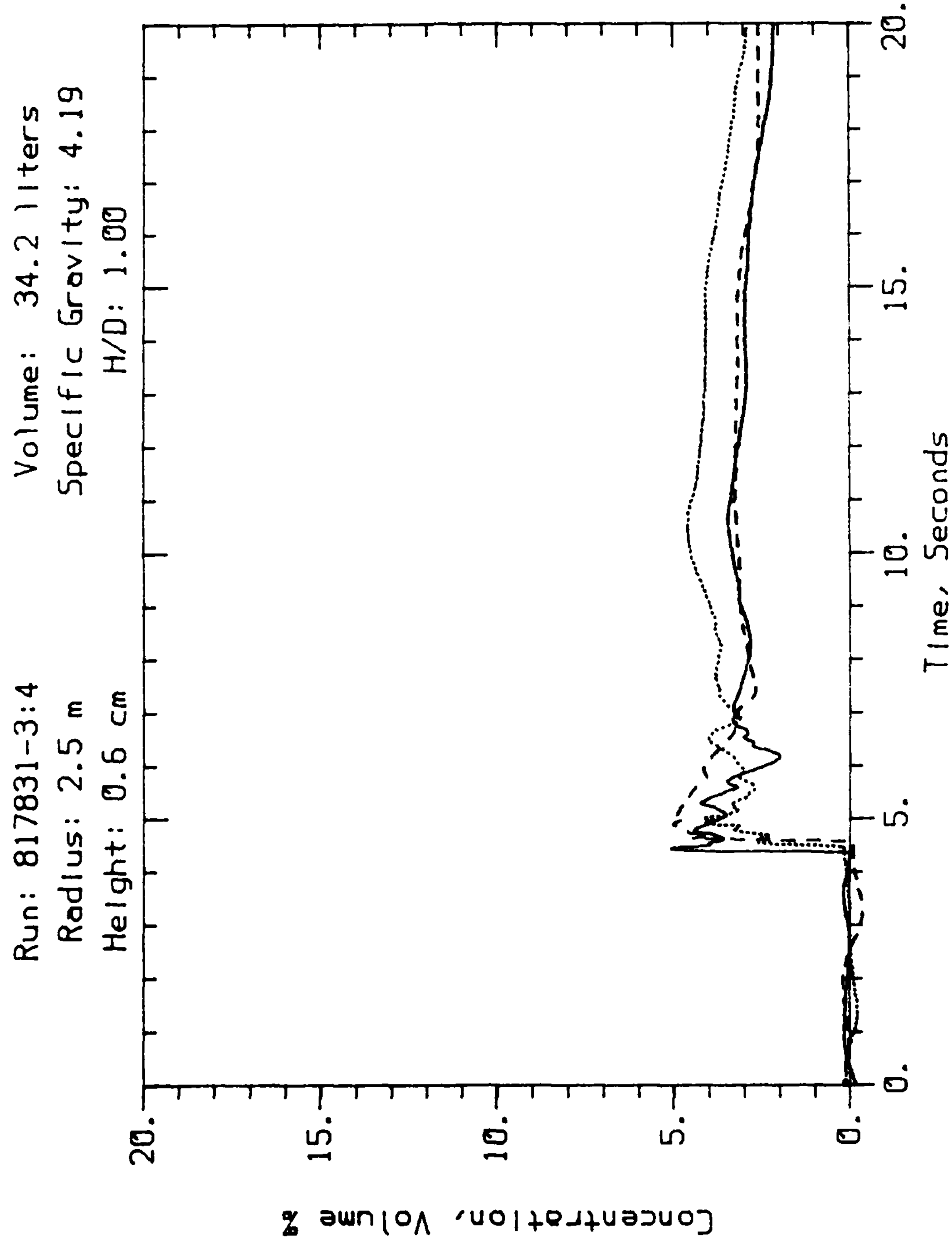
Run		Example	Plotted Line Type
First	MDDYY1:C	817831:5	————————
Second	MDDYY2:C	817832:5	- - - - - - -
Third	MDDYY3:C	817833:5	. . . .

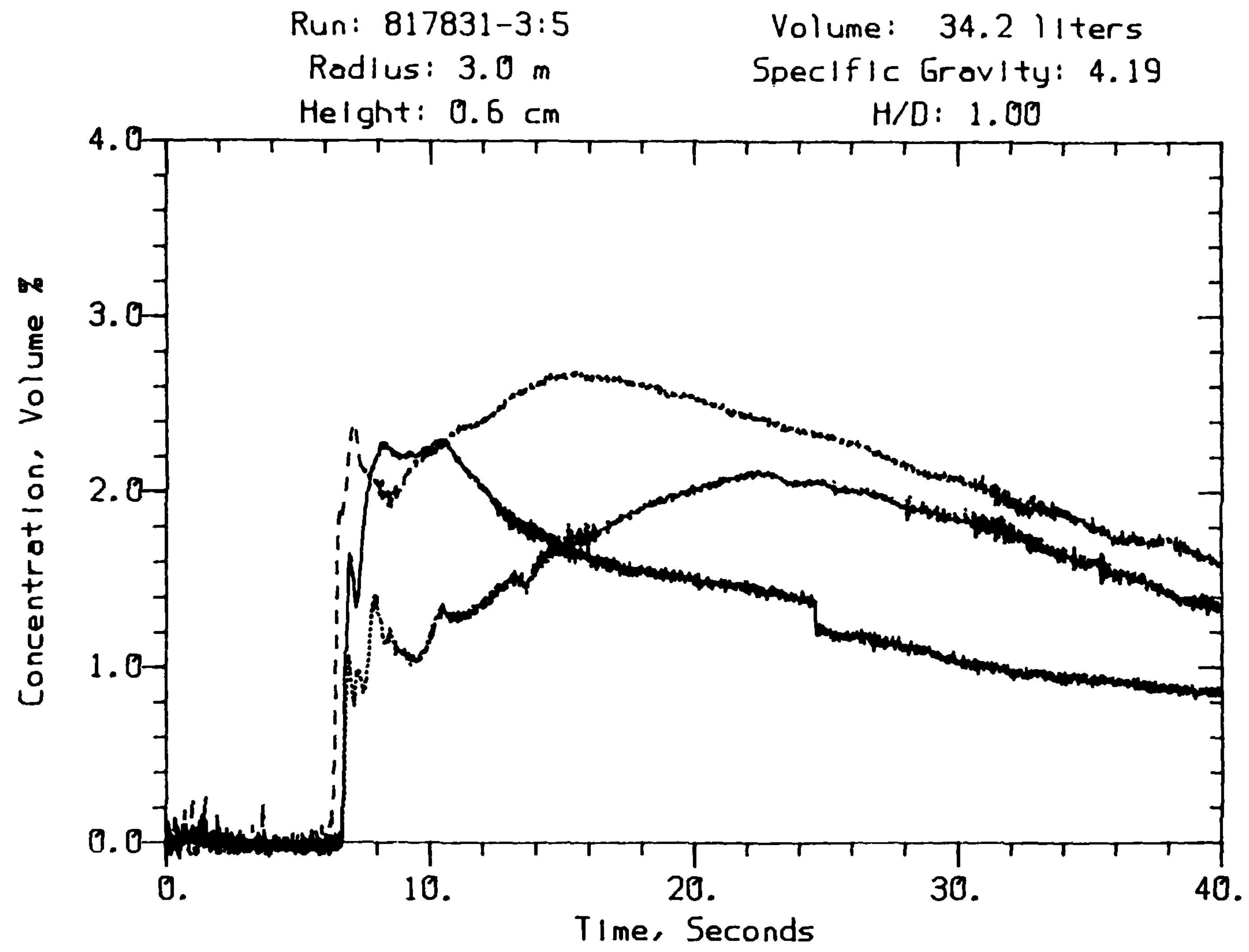
where: M = single character month designation
DD = day of month
YY = two-digit year
C = channel number

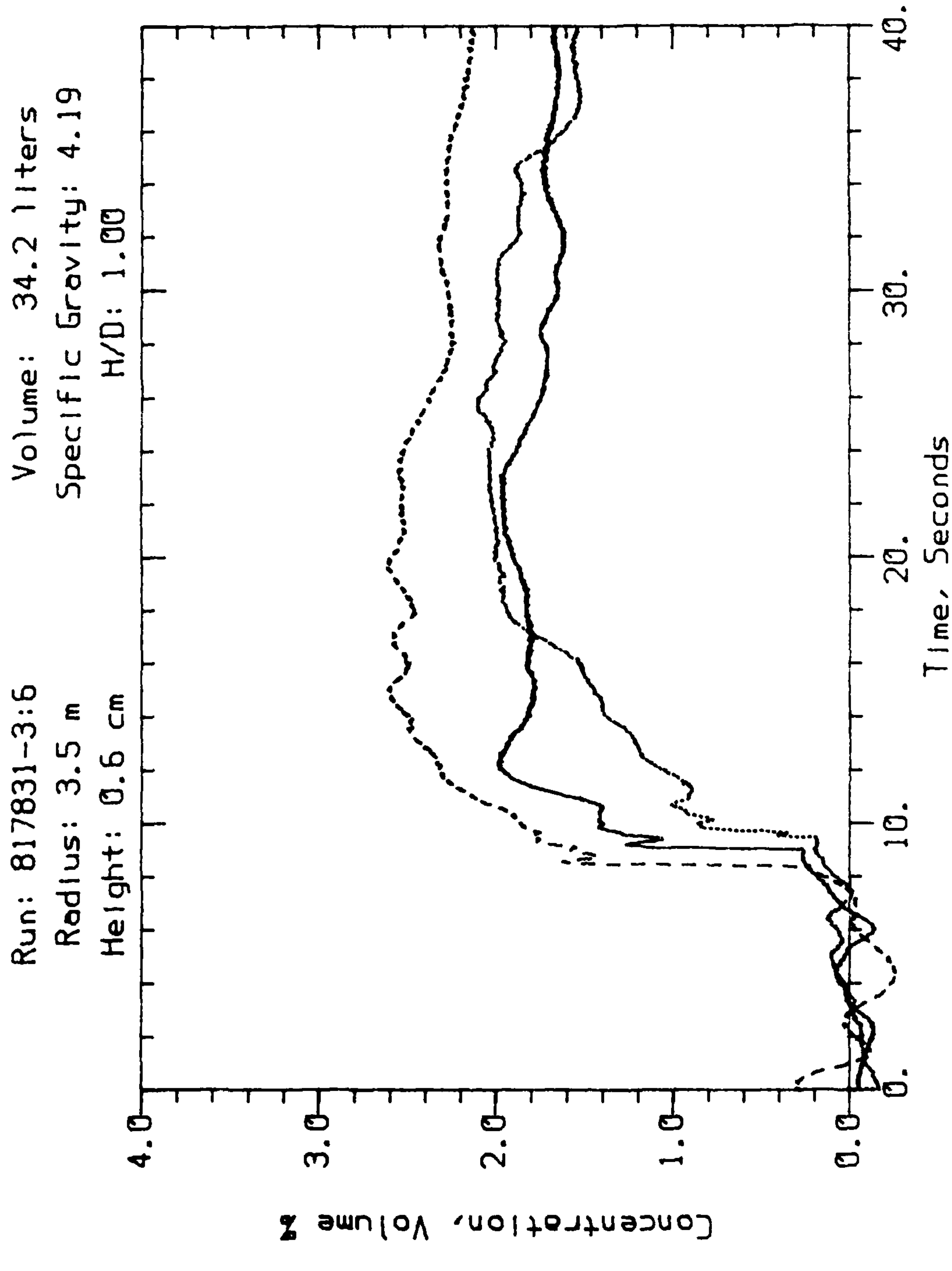

Run: 817831-3:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
60.
45.
30.
15.
0.
0.
5.
10.
15.
20.
Time, Seconds

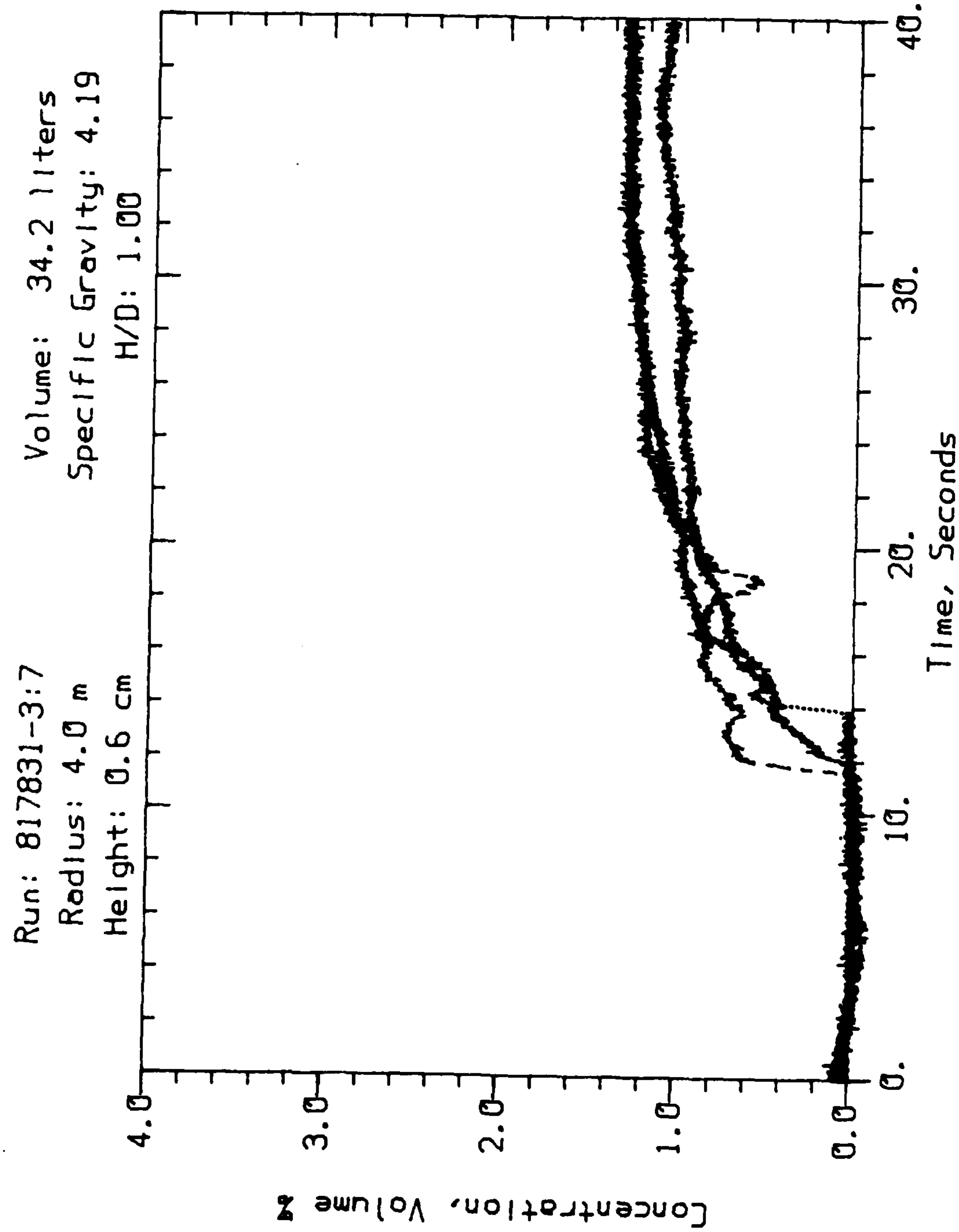

Run: 817831-3:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

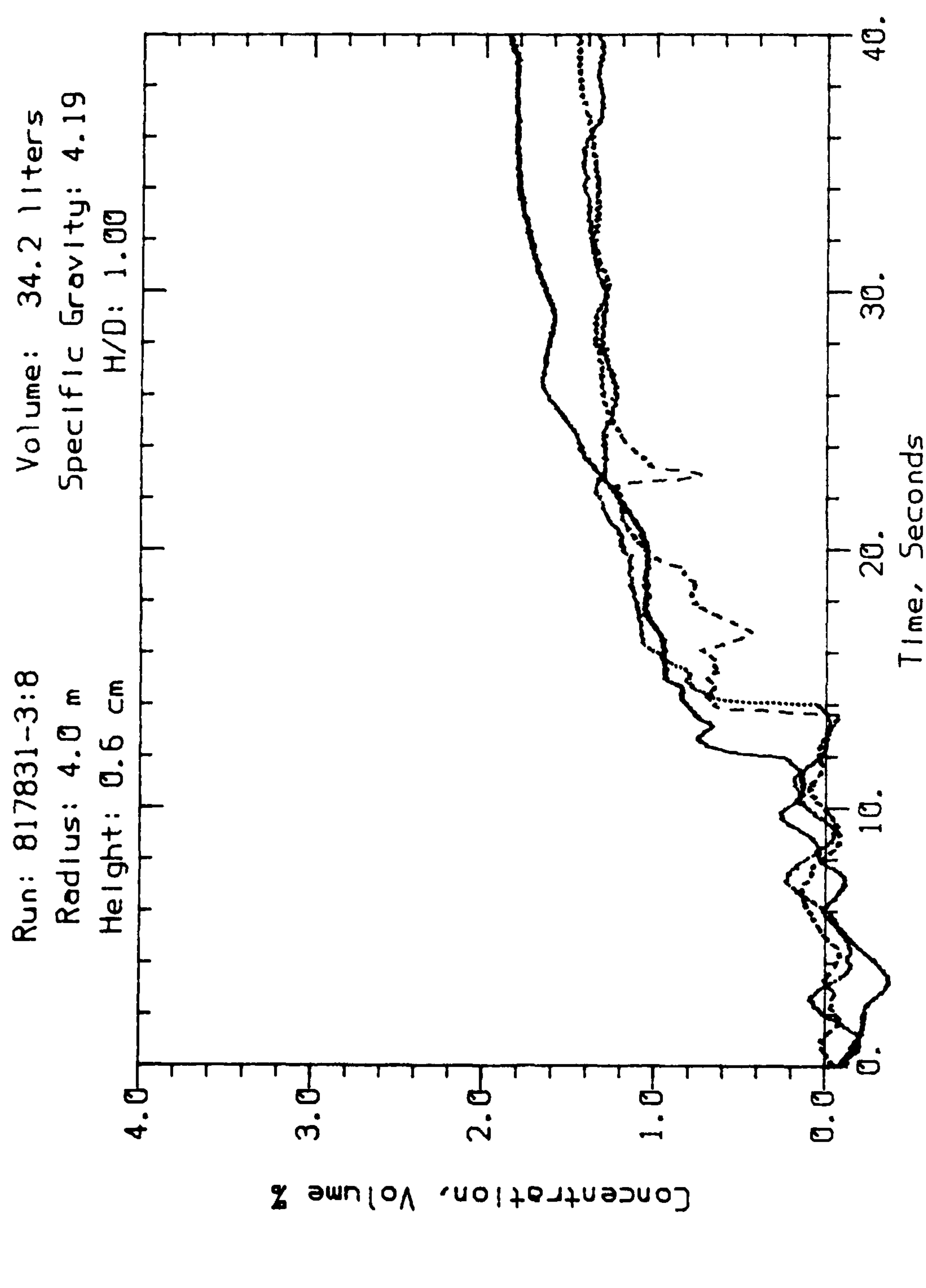

Run: 817831-3:3
Radius: 2.0 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
5.
10.
15.
20.

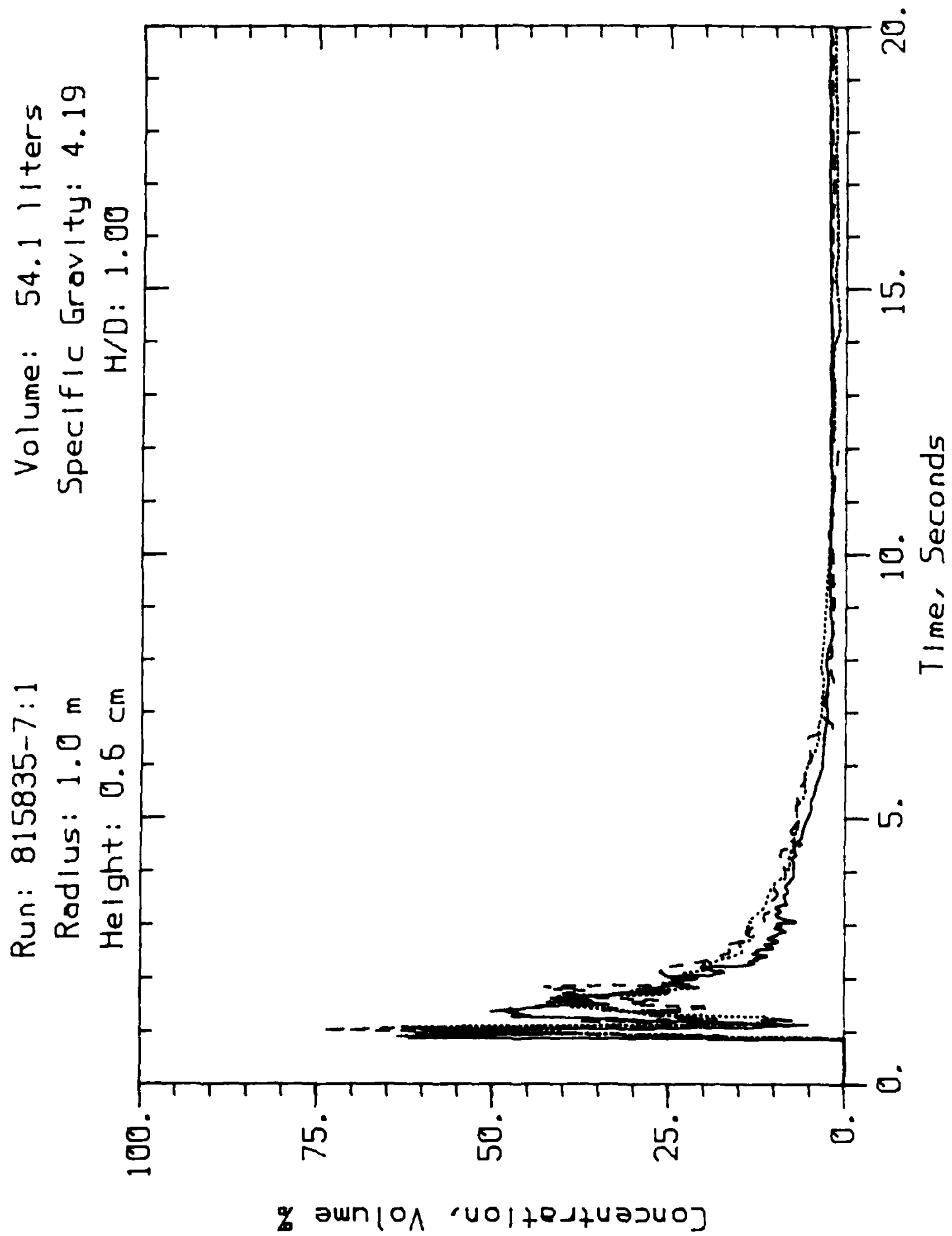

Run: 817831-3:4
Radius: 2.5 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
20.
15.
10.
5.
0.
Time, Seconds

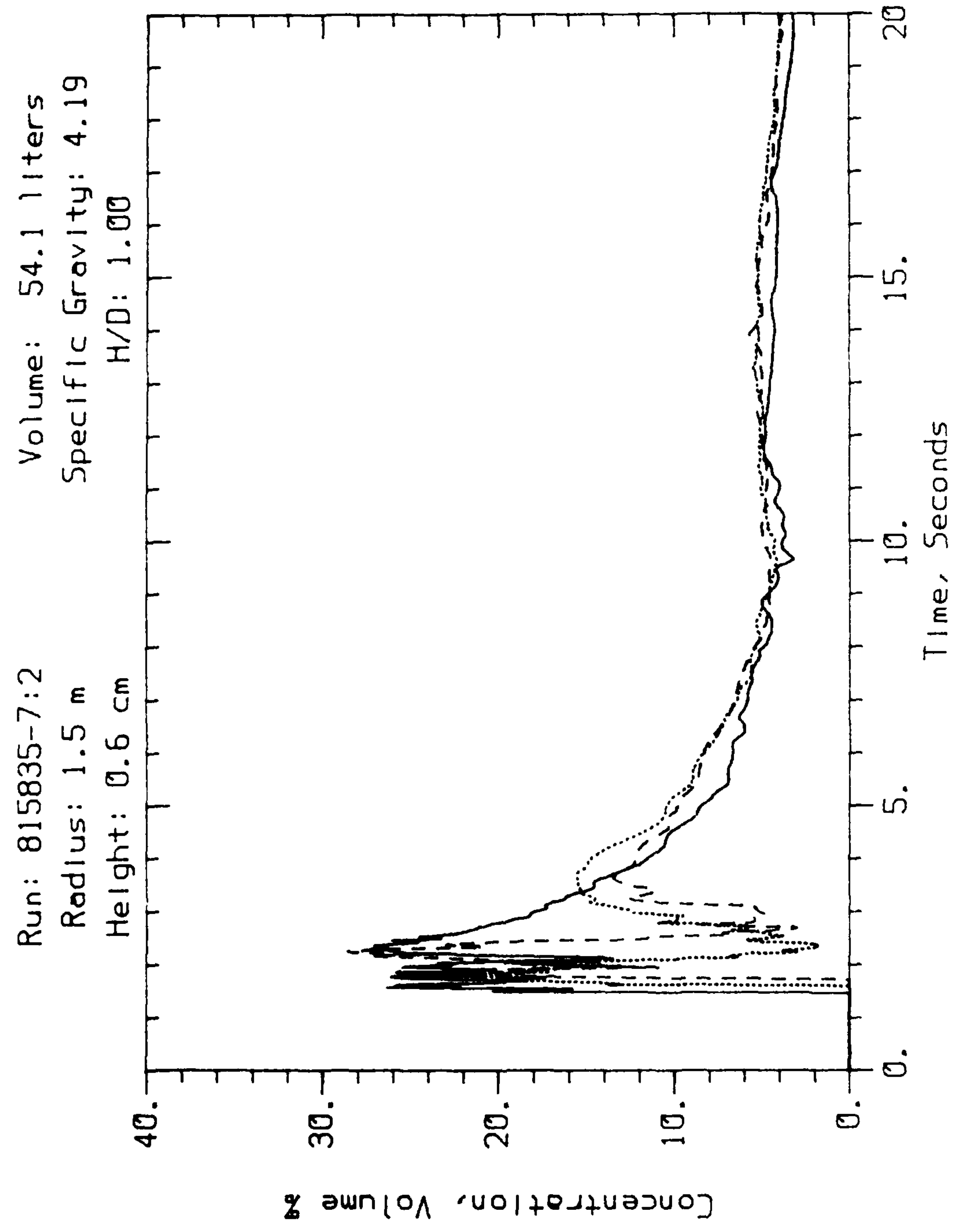

Run: 817831-3:5
Radius: 3.0 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
0.
10.
20.
30.
40.
Time, Seconds

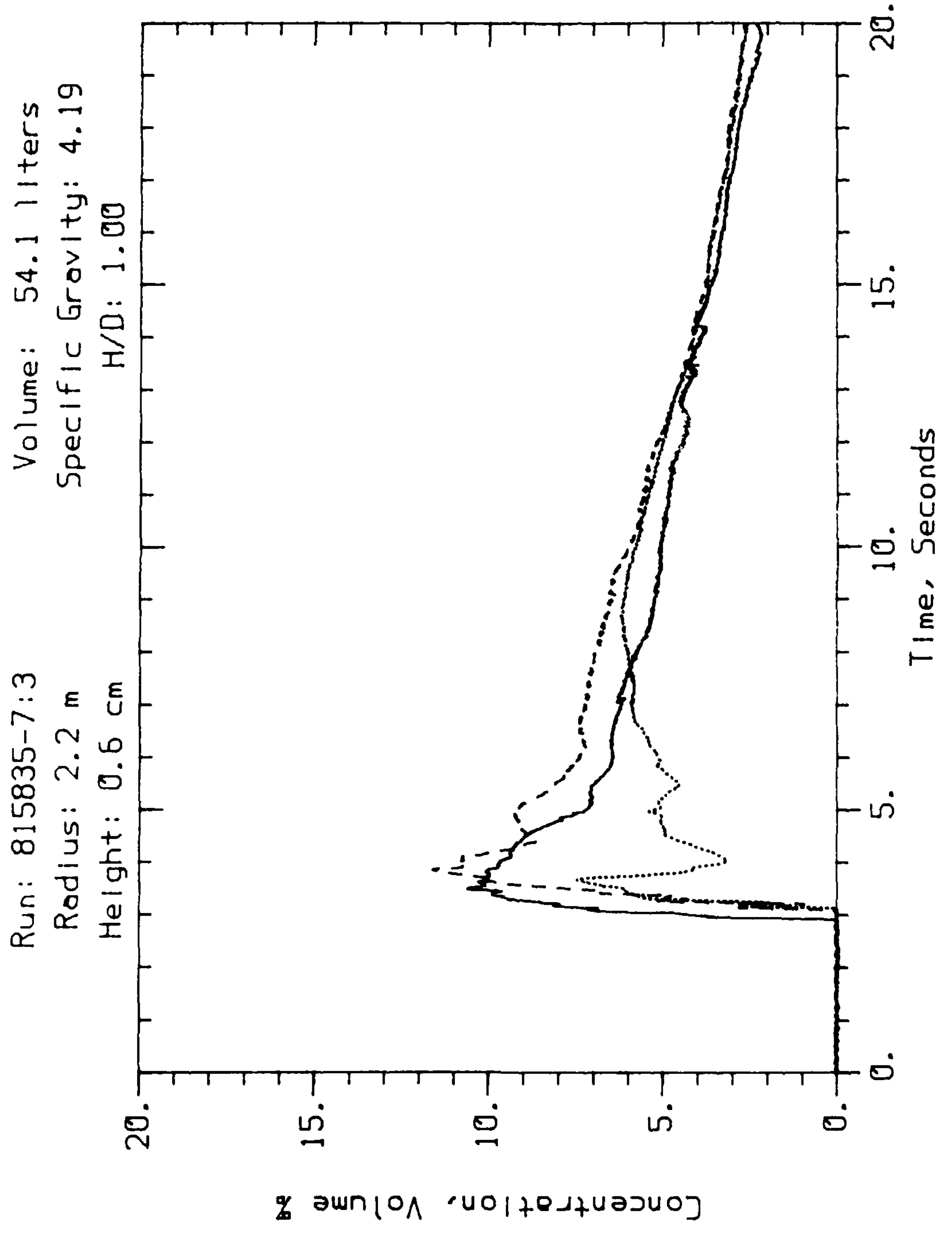

Run: 817831-3:6
Radius: 3.5 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
0.
10.
20.
30.
40.
Time, Seconds


Run: 817831-3:7
Radius: 4.0 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 4.19
H/D: 1.00
0.
10.
20.
30.
40.
Time, Seconds
0.0
1.0
2.0
3.0
4.0
Concentration, Volume %

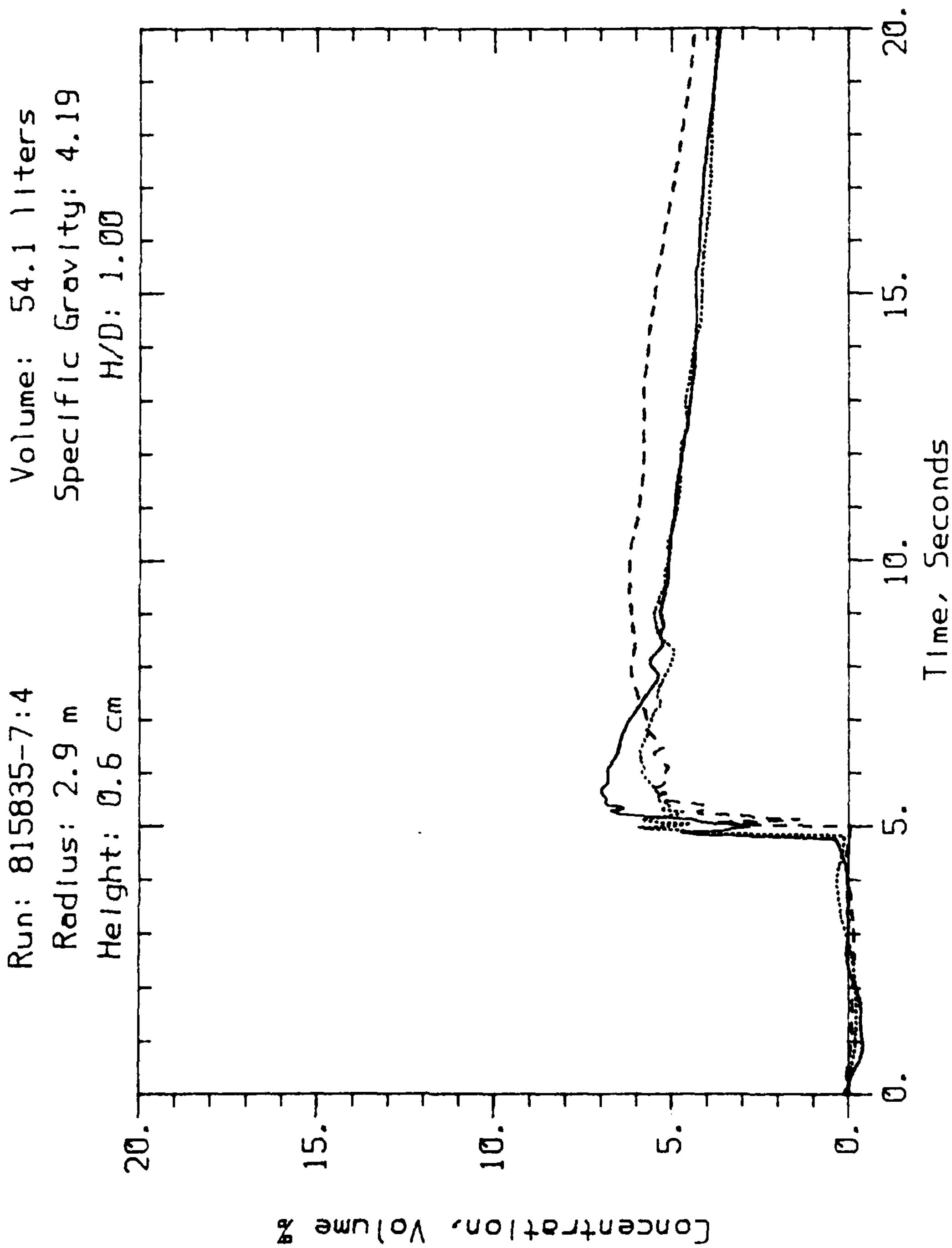

Run: 817831-3:8
Radius: 4.0 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
10.
20.
30.
40.

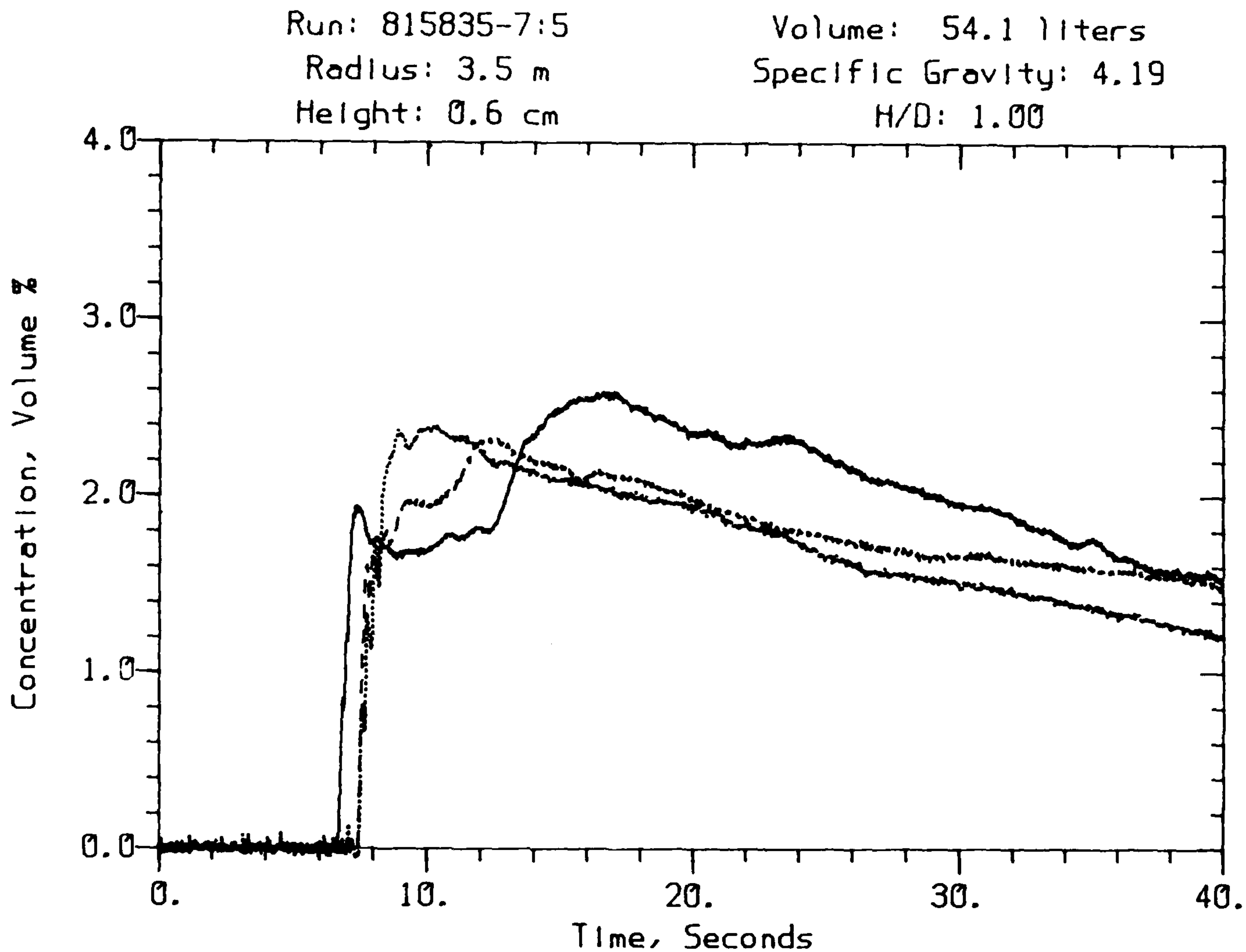

Run: 815835-7:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
100.
75.
50.
25.
0.
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

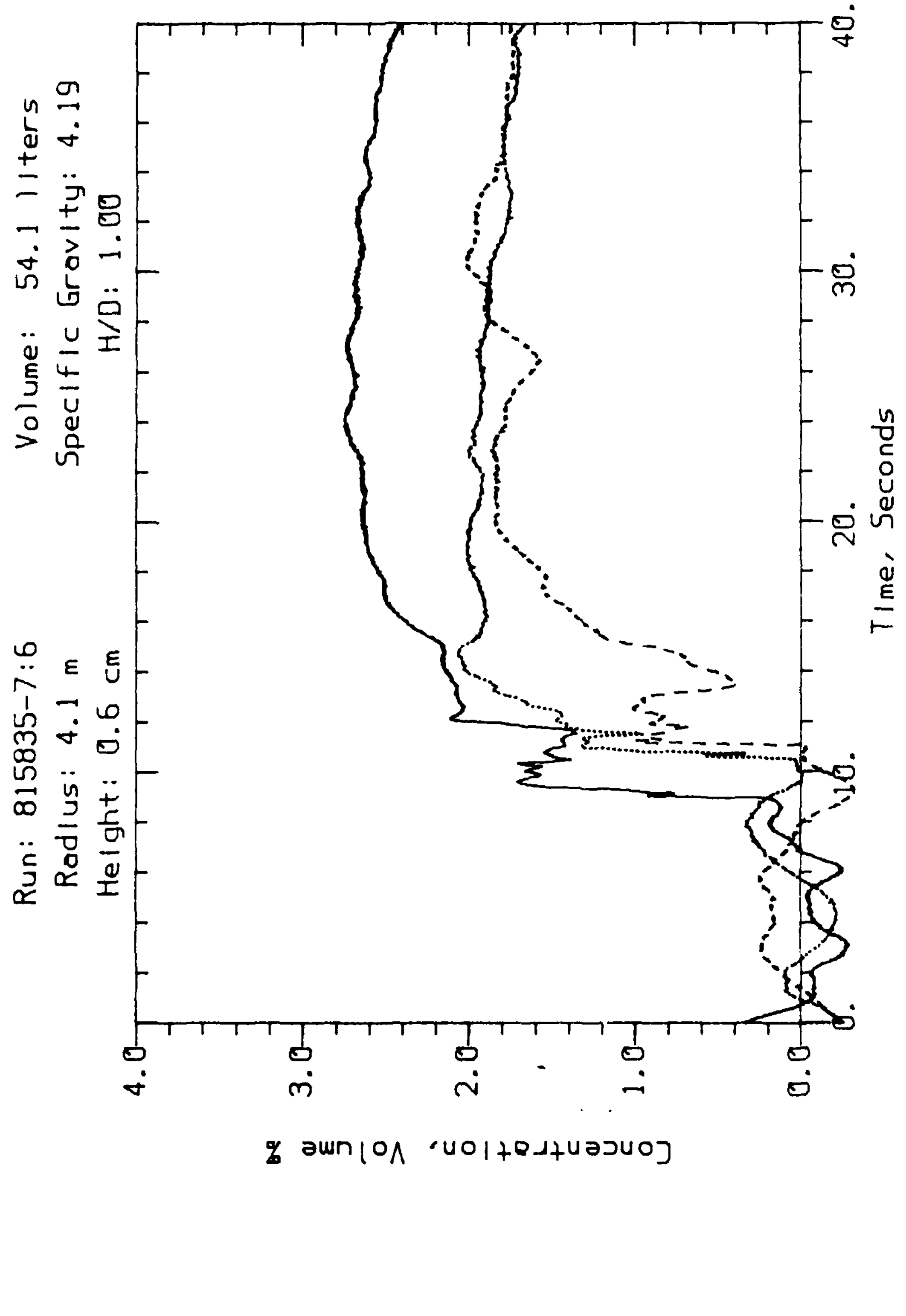

Run: 815835-7:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.
10.
20.
30.
40.
Concentration, Volume %



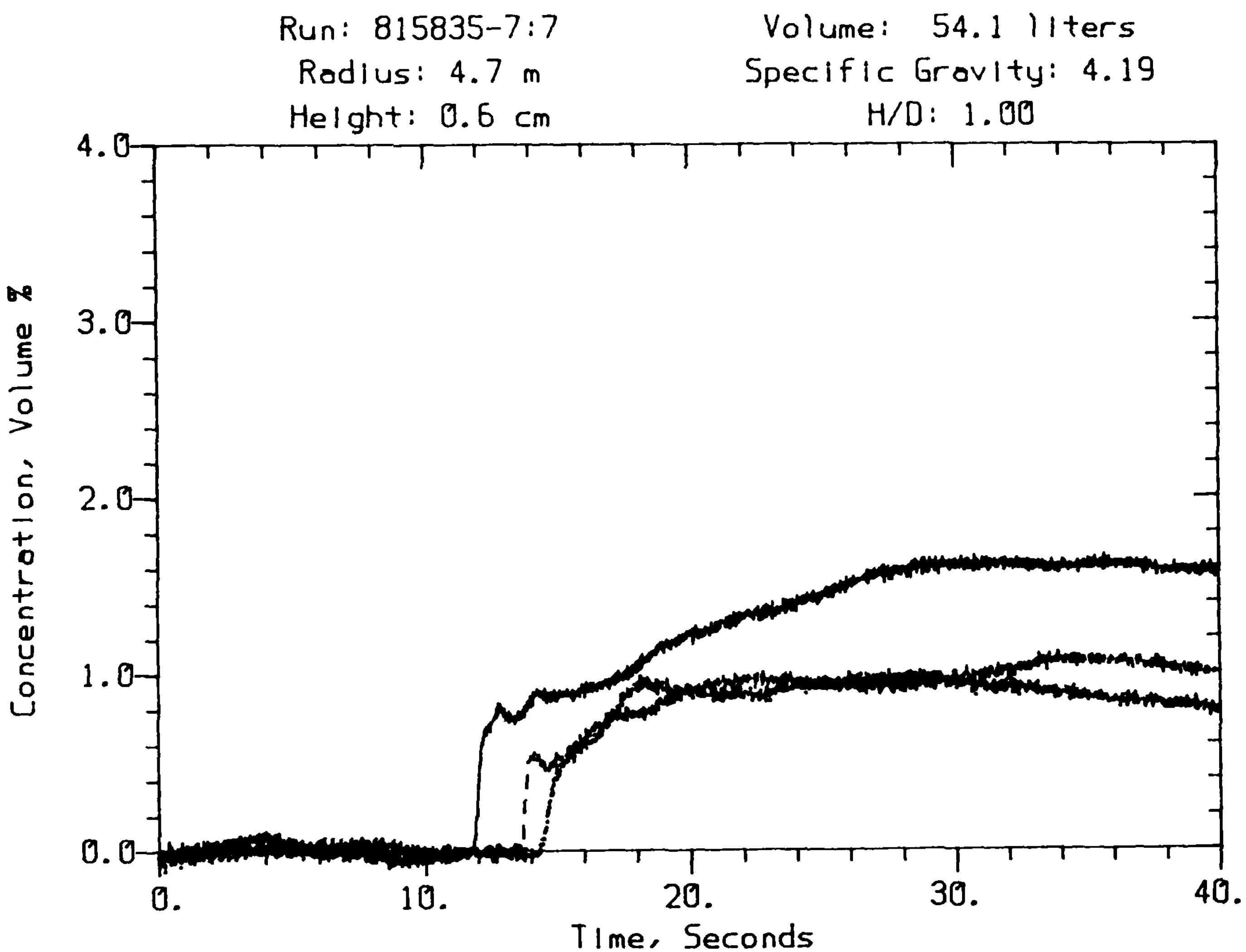
Run: 815835-7:3
Radius: 2.2 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Time, Seconds
Concentration, Volume %
0.
5.
10.
15.
20.

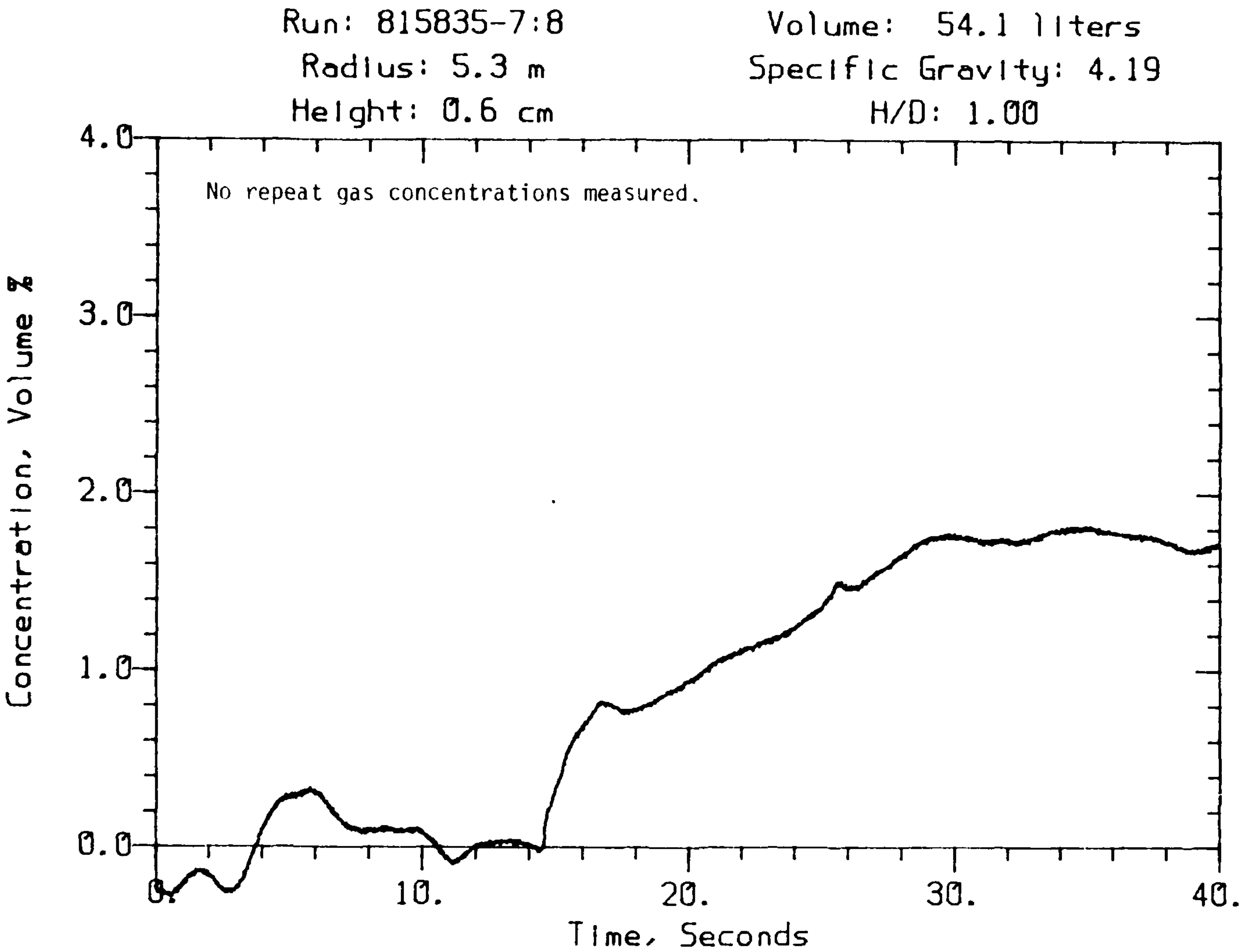

Run: 815835-7:4
Radius: 2.9 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
20.
15.
10.
5.
0.
Time, Seconds
0.
5.
10.
15.
20.

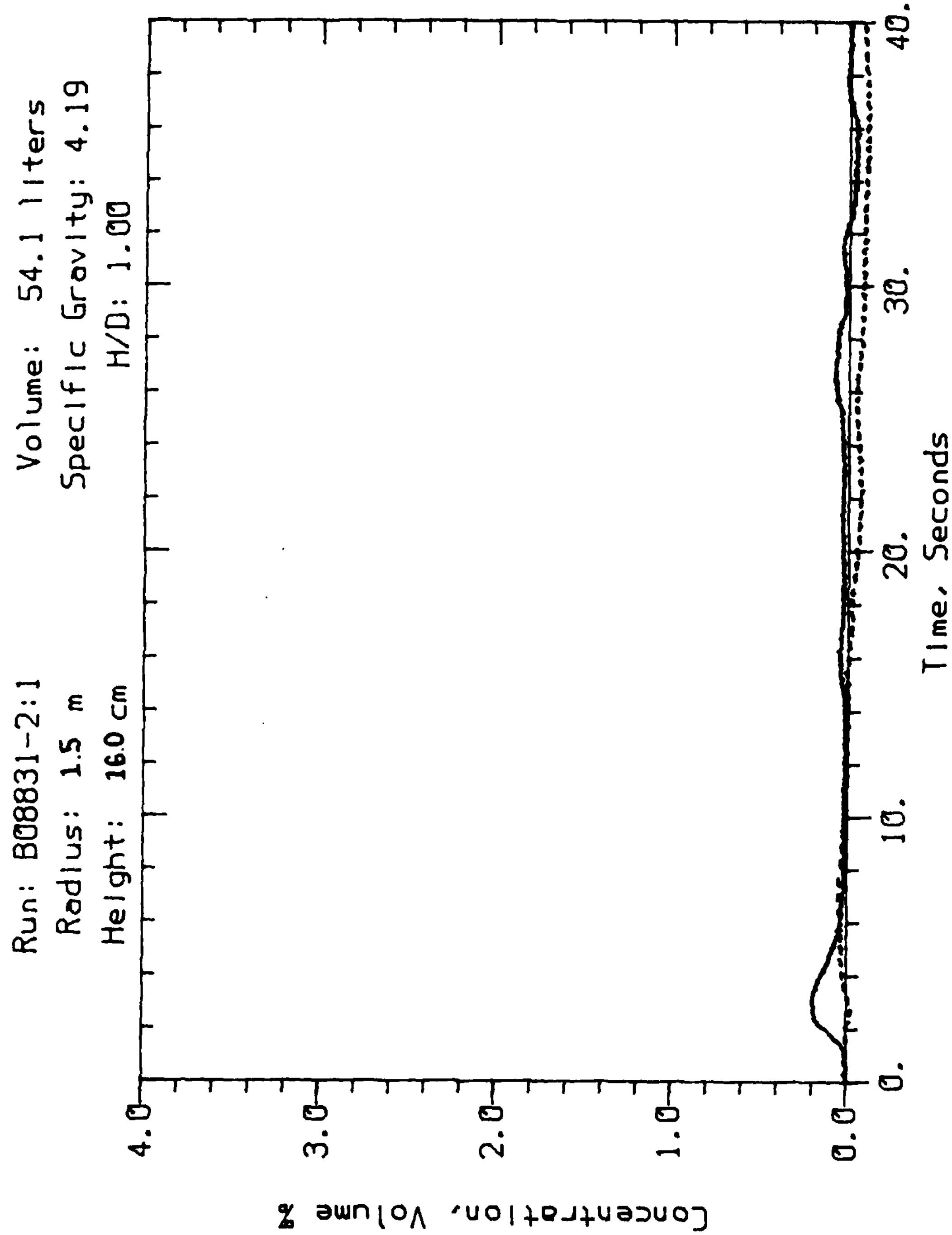

Run: 815835-7:5
Radius: 3.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
4.0
3.0
2.0
1.0
0.0
Concentration, Volume %
0.
10.
20.
30.
40.
Time, Seconds

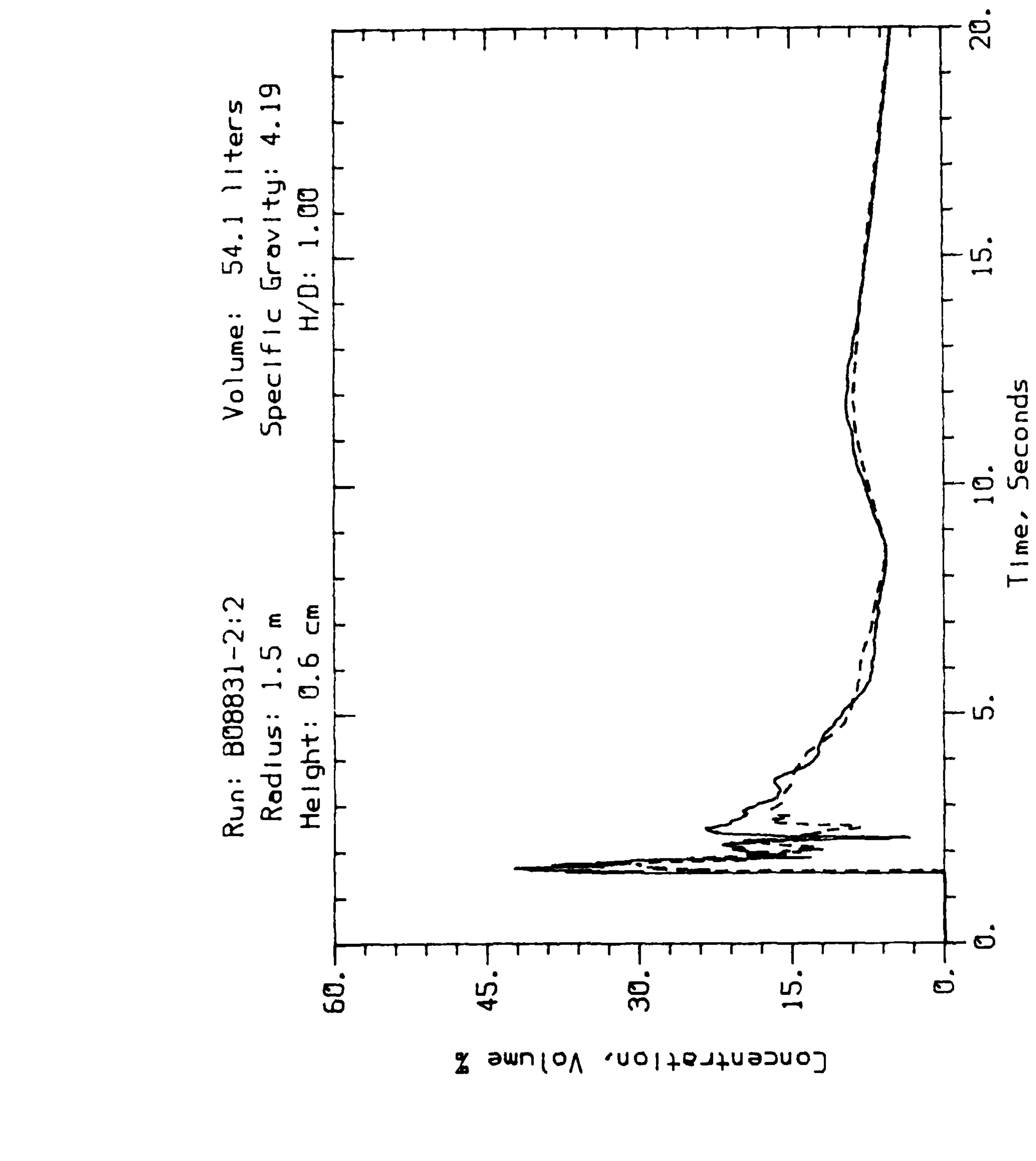


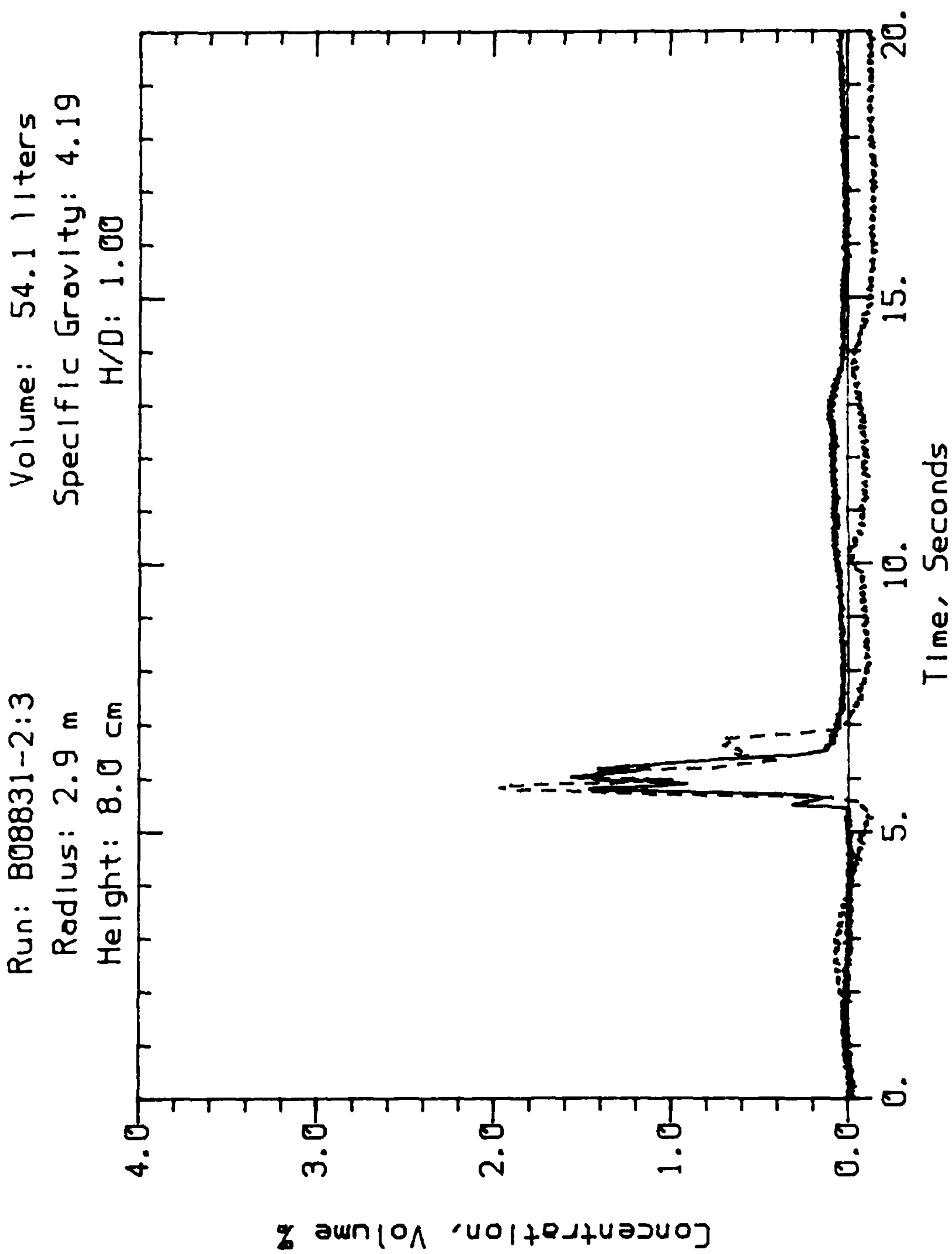
Run: 815835-7:6
Radius: 4.1 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
10.
20.
30.
40.
Time, Seconds
0.0
1.0
2.0
3.0
4.0
Concentration, Volume %

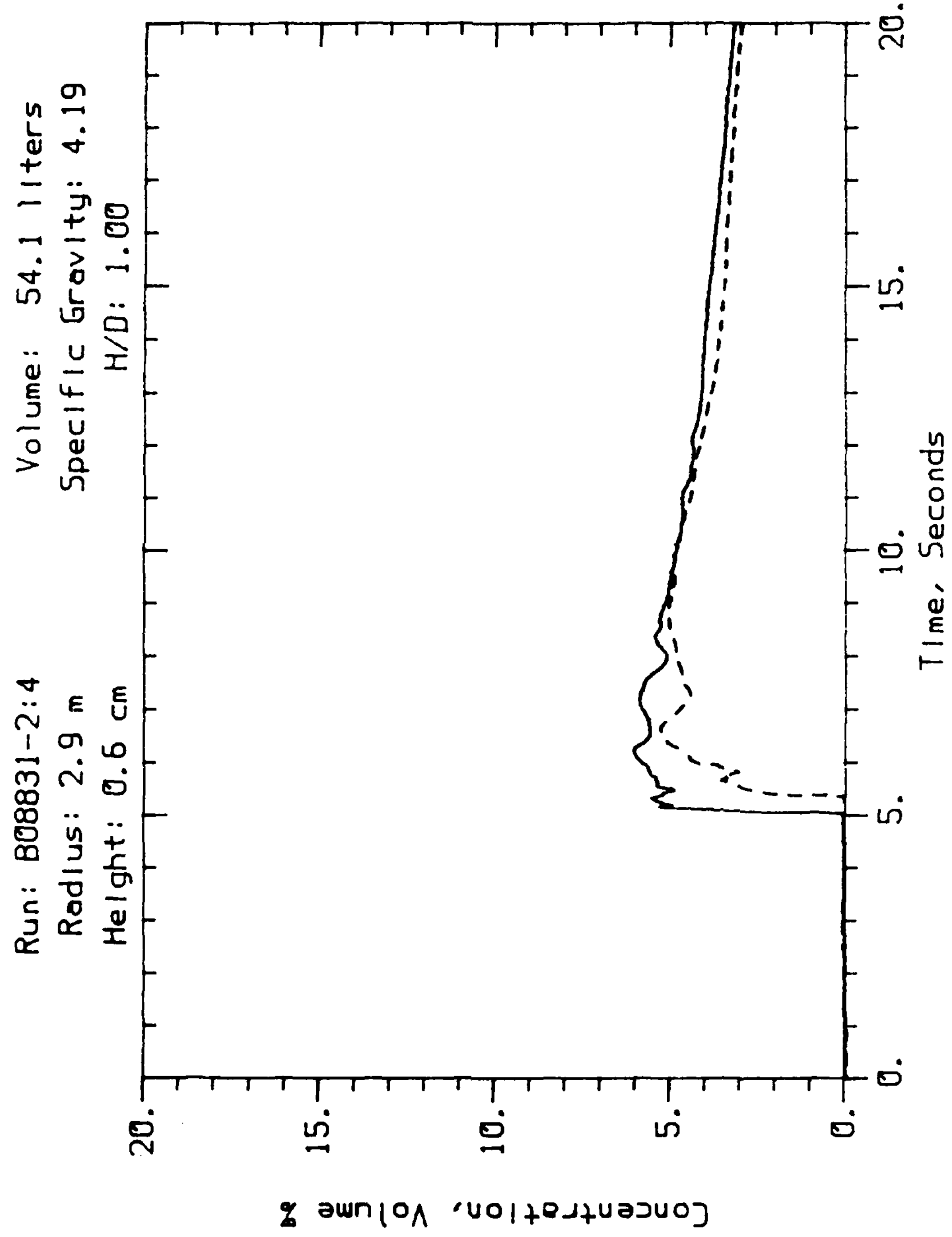

Run: 815835-7:7
Radius: 4.7 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
0.
10.
20.
30.
40.
Time, Seconds


Run: 815835-7:8
Radius: 5.3 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
No repeat gas concentrations measured.
Concentration, Volume %
4.0
3.0
2.0
1.0
0.0
0.
10.
20.
30.
40.
Time, Seconds

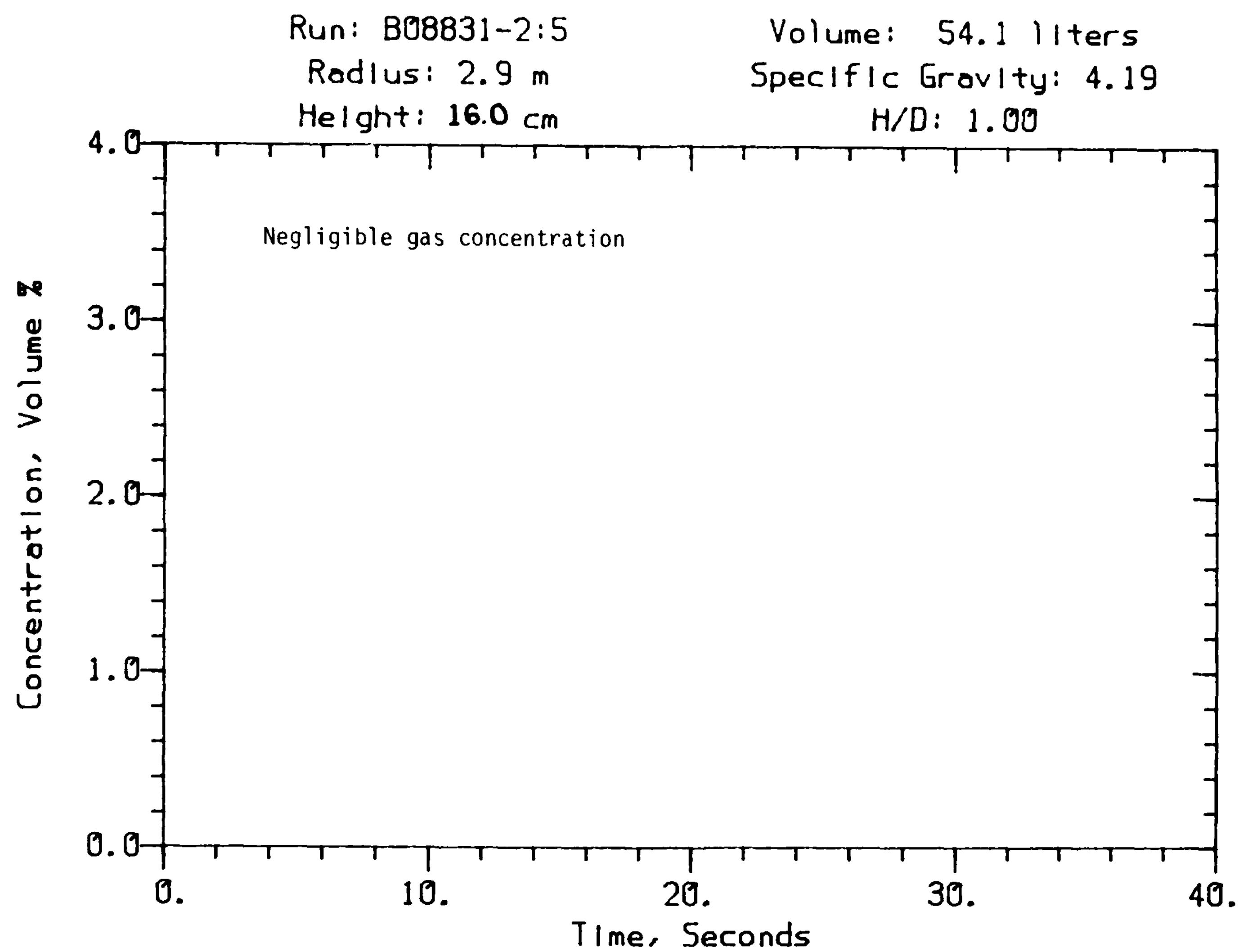

Run: B08831-2:1
Radius: 1.5 m
Height: 16.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
10.
20.
30.
40.
Time, Seconds
0.0
1.0
2.0
3.0
4.0
Concentration, Volume %

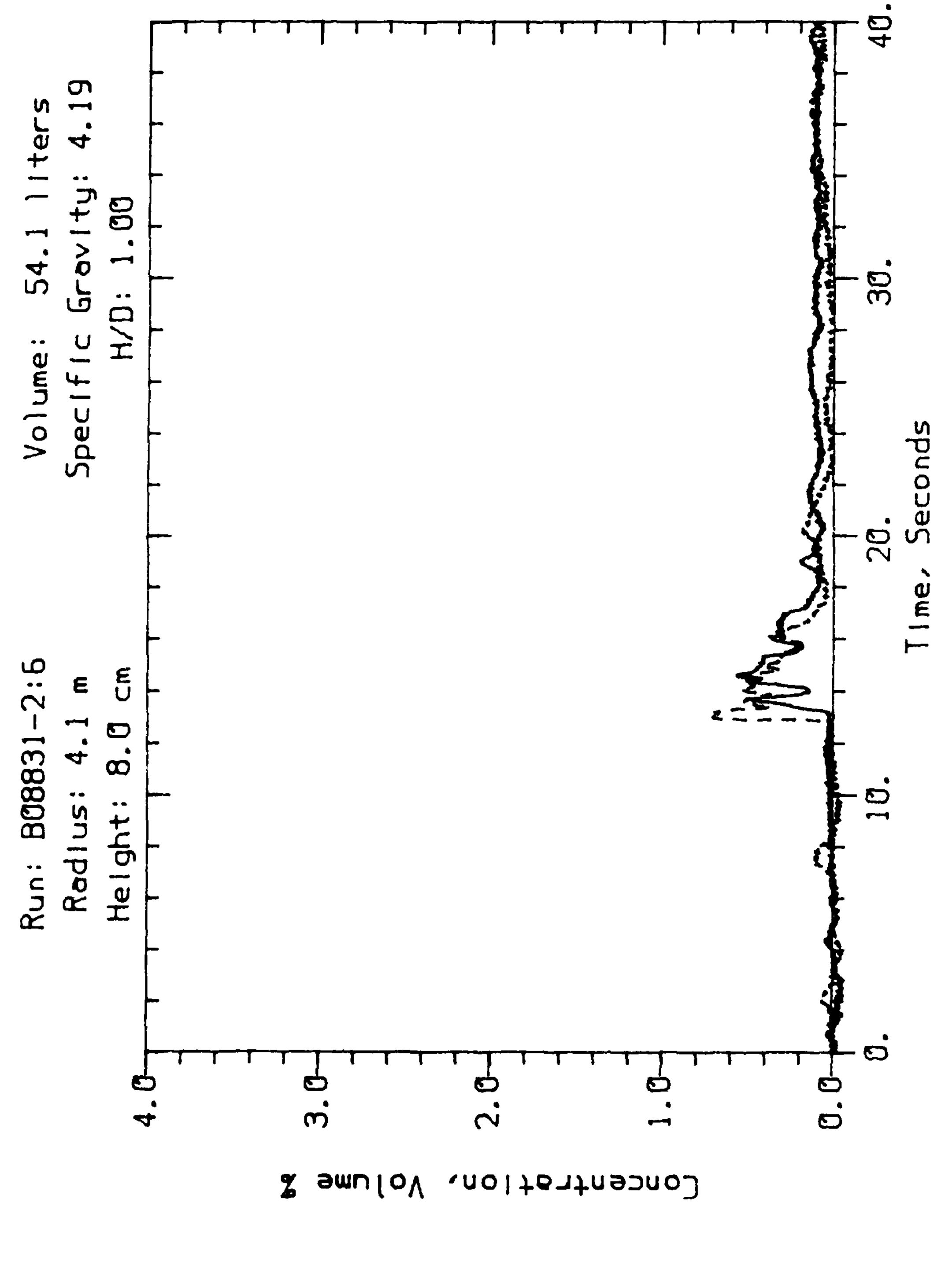

Run: B08831-2:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
60.
45.
30.
15.
0.
0.
5.
10.
15.
20.
Time, Seconds

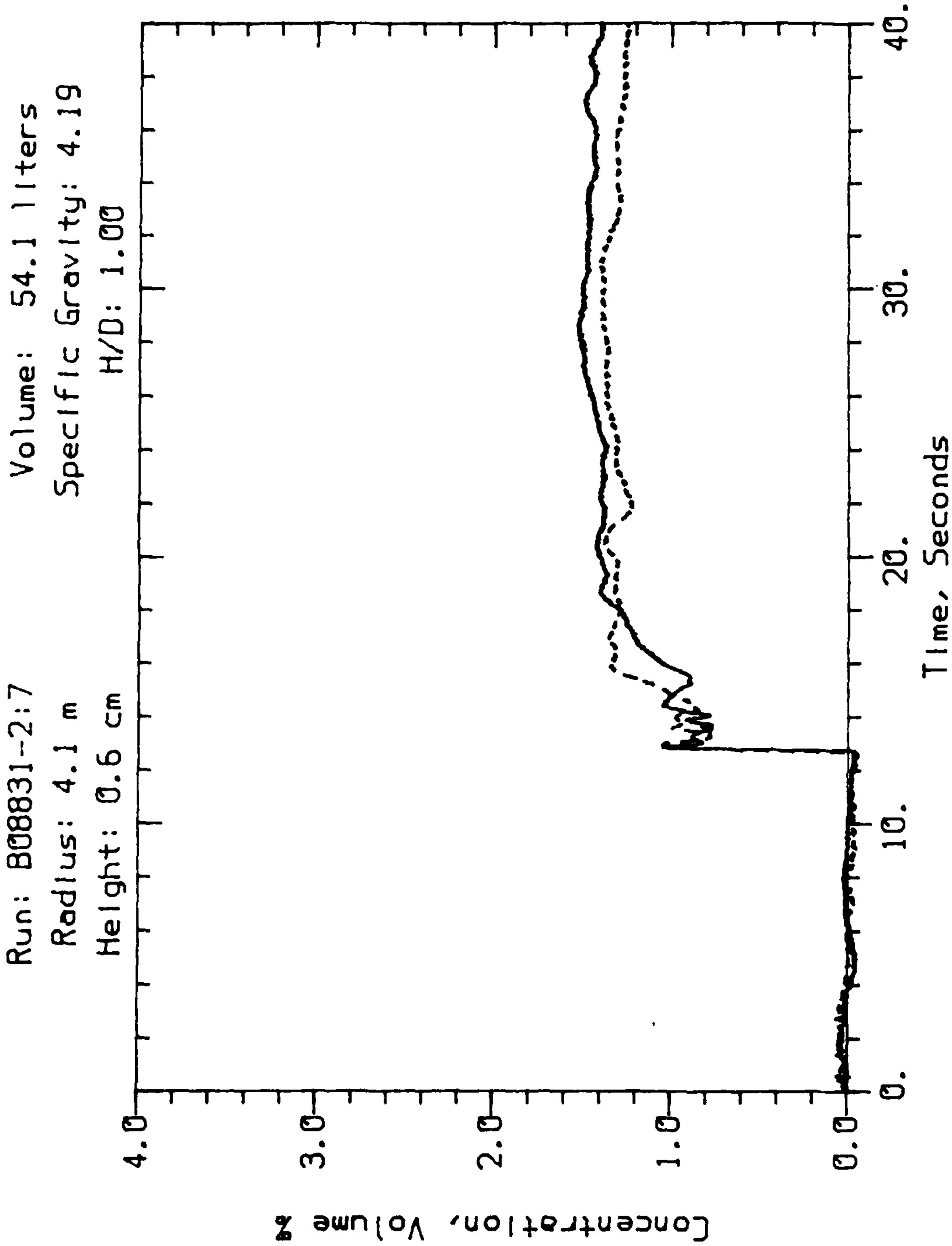

Run: B08831-2:3
Radius: 2.9 m
Height: 8.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
5.
10.
15.
20.

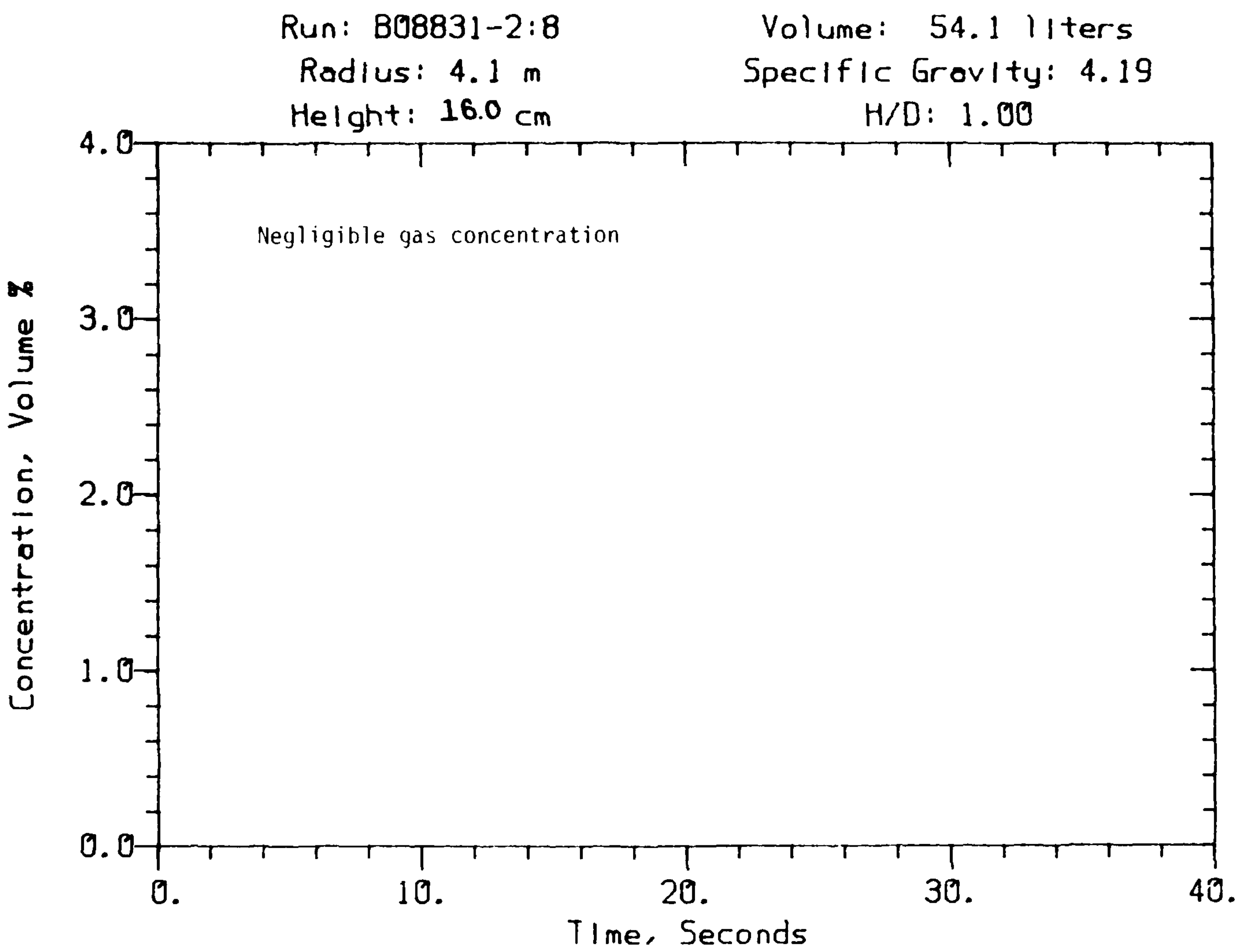


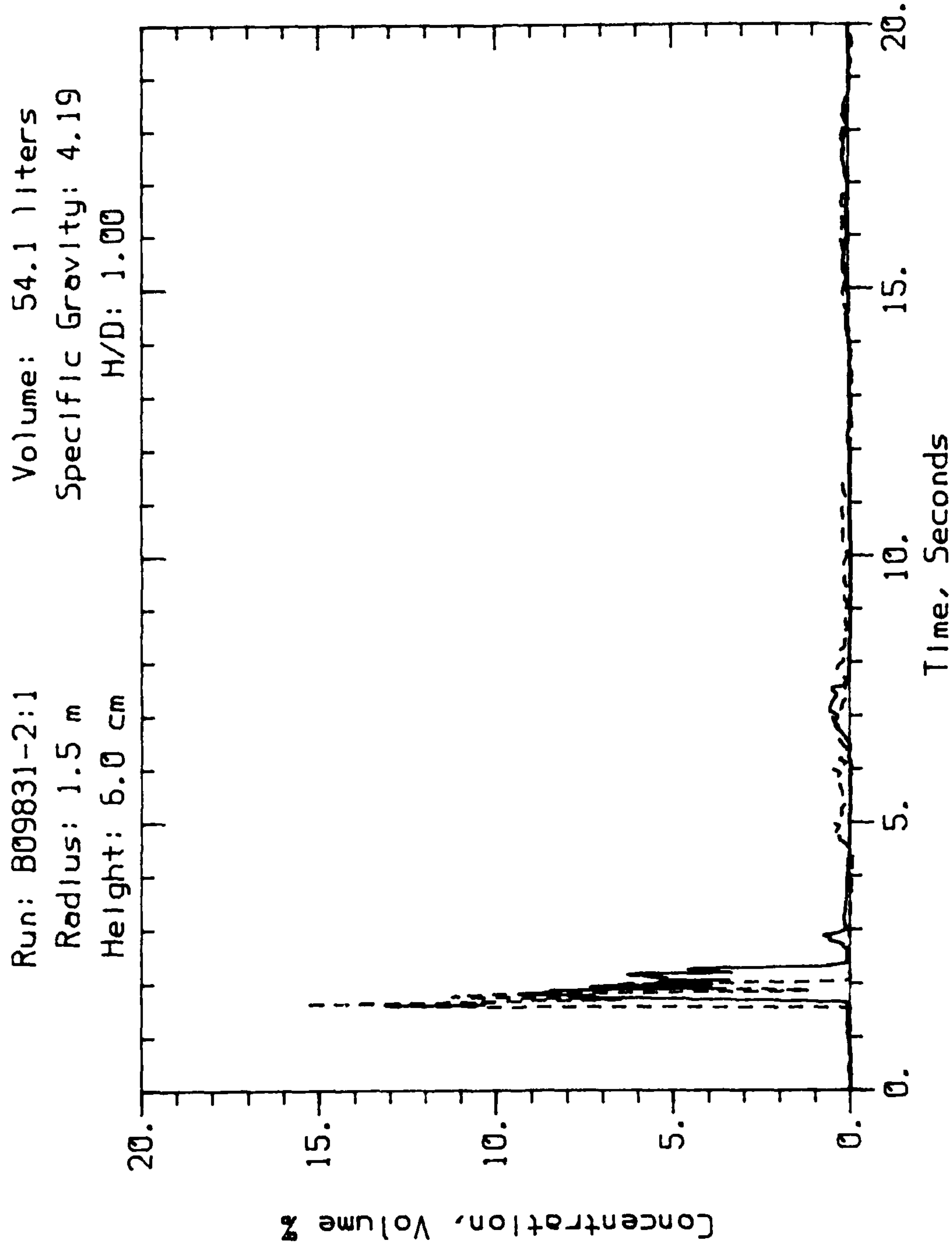
Run: B08831-2:4
Radius: 2.9 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
Concentration, Volume %


Run: B08831-2:5
Radius: 2.9 m
Height: 16.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Negligible gas concentration
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
0.
10.
20.
30.
40.
Time, Seconds

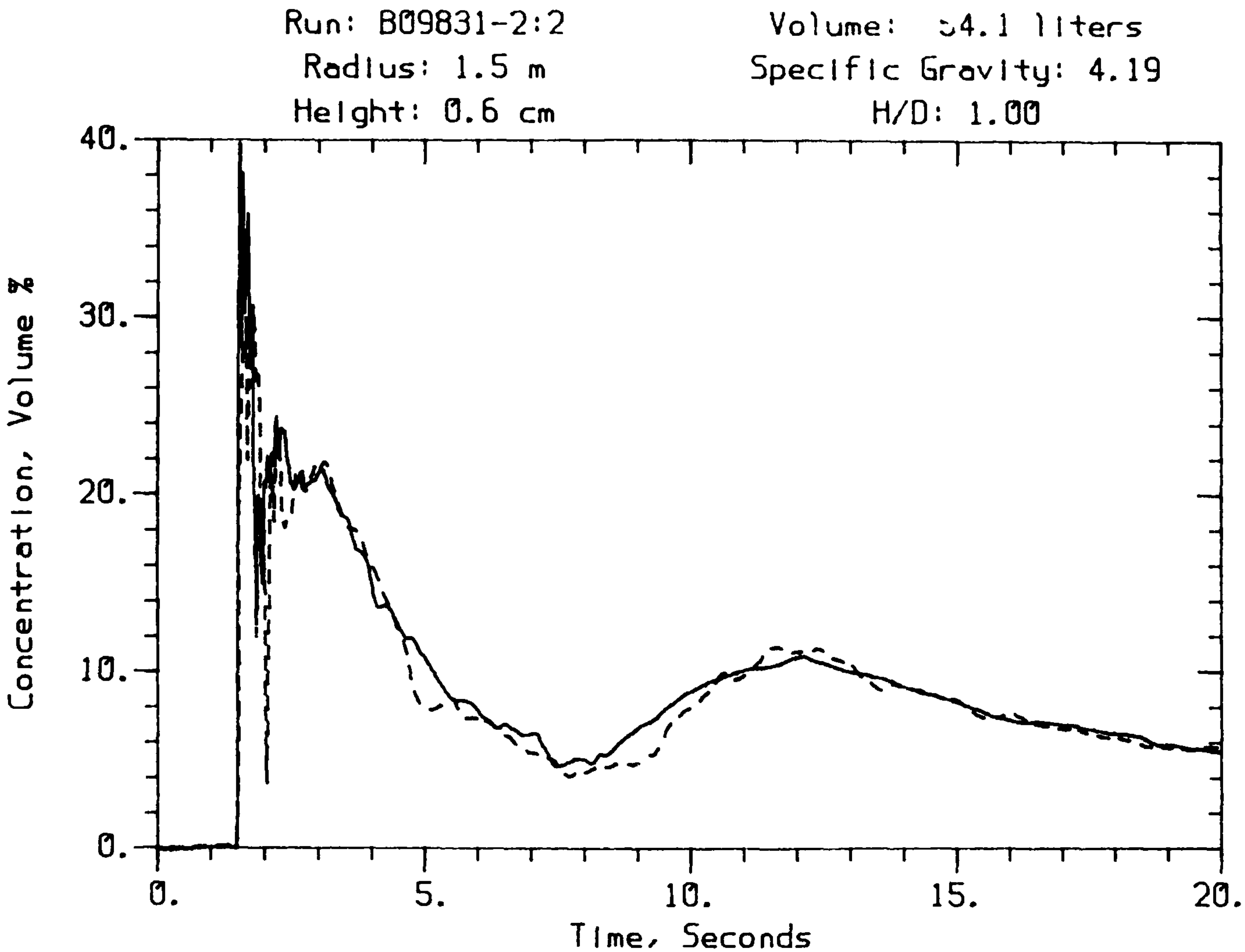

Run: B08831-2:6
Radius: 4.1 m
Height: 8.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
10.
20.
30.
40.

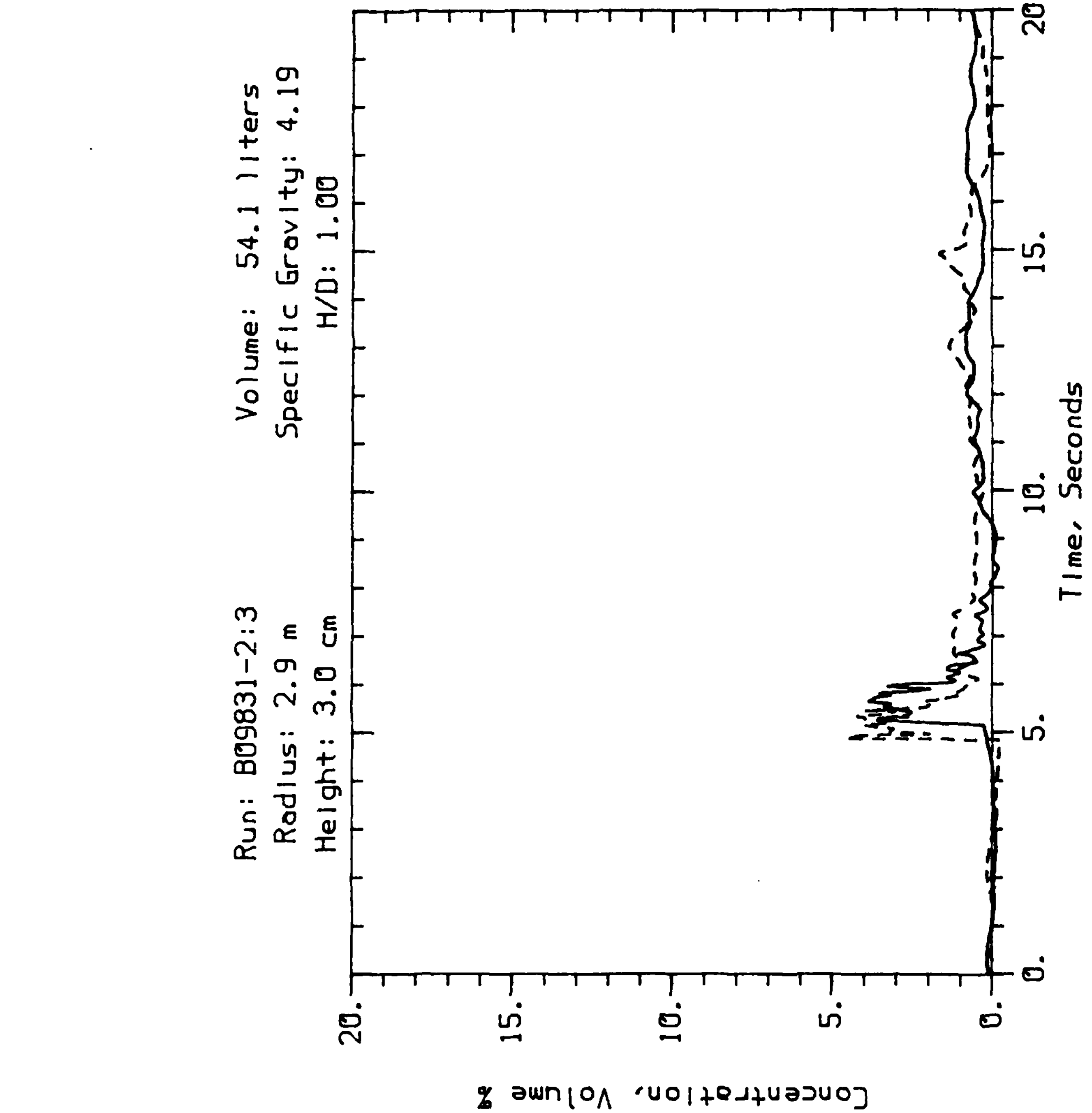

Run: B08831-2:7
Radius: 4.1 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.0
1.0
2.0
3.0
4.0
0.
10.
20.
30.
40.


Run: B08831-2:8
Radius: 4.1 m
Height: 16.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Negligible gas concentration
Concentration, Volume %
4.0
3.0
2.0
1.0
0.0
0.
10.
20.
30.
40.
Time, Seconds

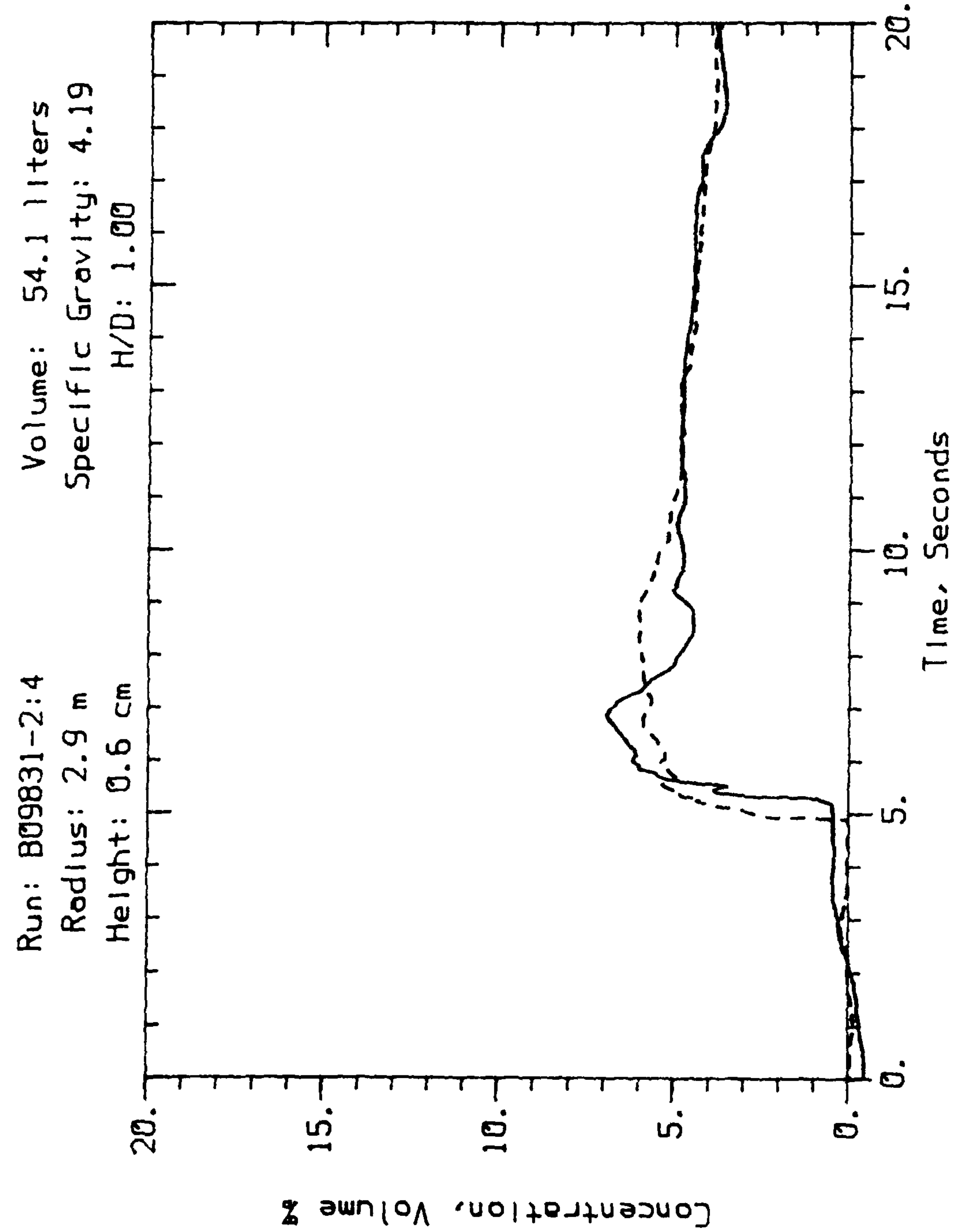


Run: B09831-2:1
Radius: 1.5 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
Concentration, Volume %

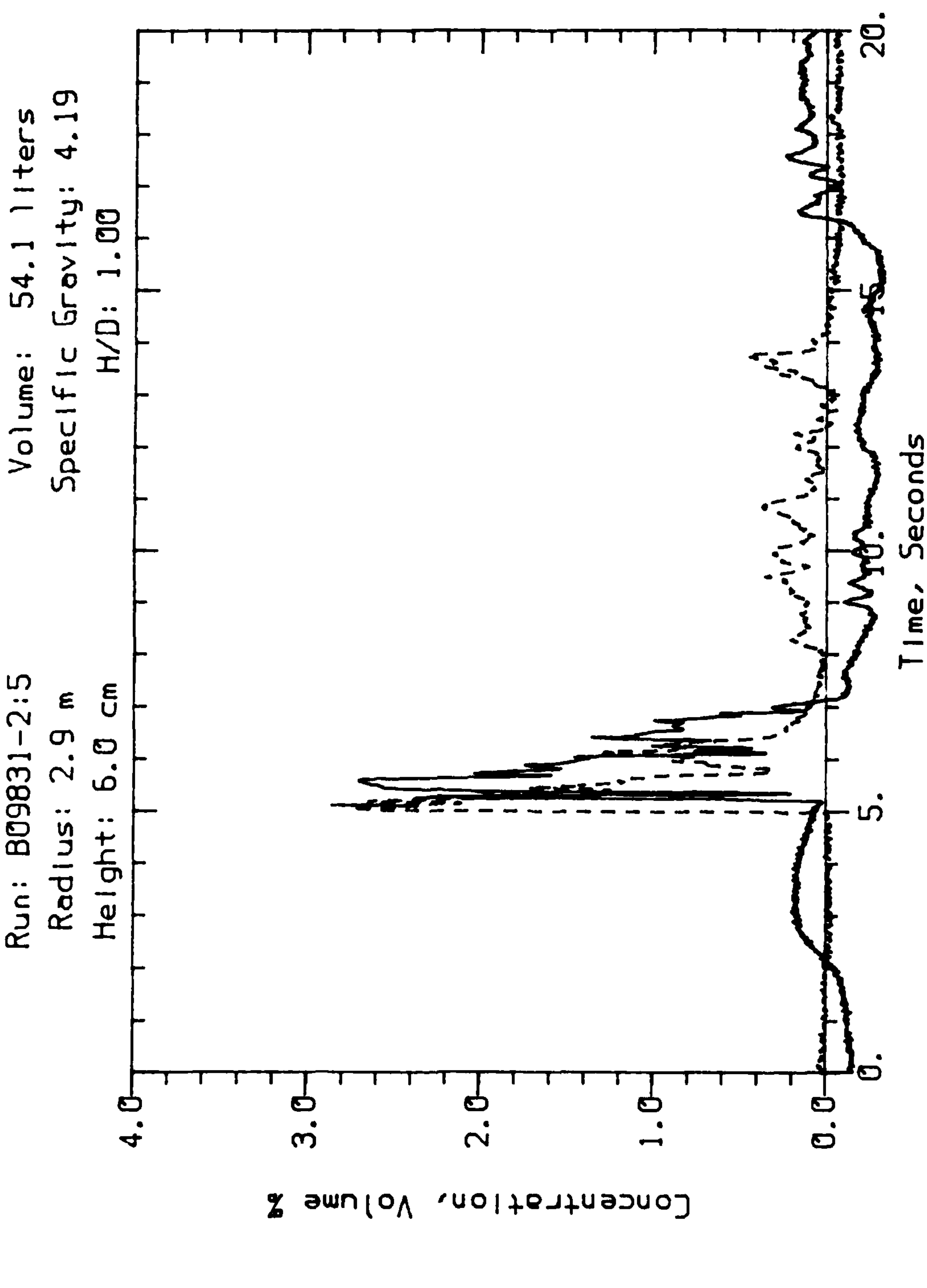

Run: B09831-2:2
Radius: 1.5 m
Height: 0.6 cm
Volume: ͜4.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
40.
30.
20.
10.
0.
0.
5.
10.
15.
20.
Time, Seconds


Run: B09831-2:3
Radius: 2.9 m
Height: 3.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Time, Seconds
Concentration, Volume %
0.
5.
10.
15.
20.

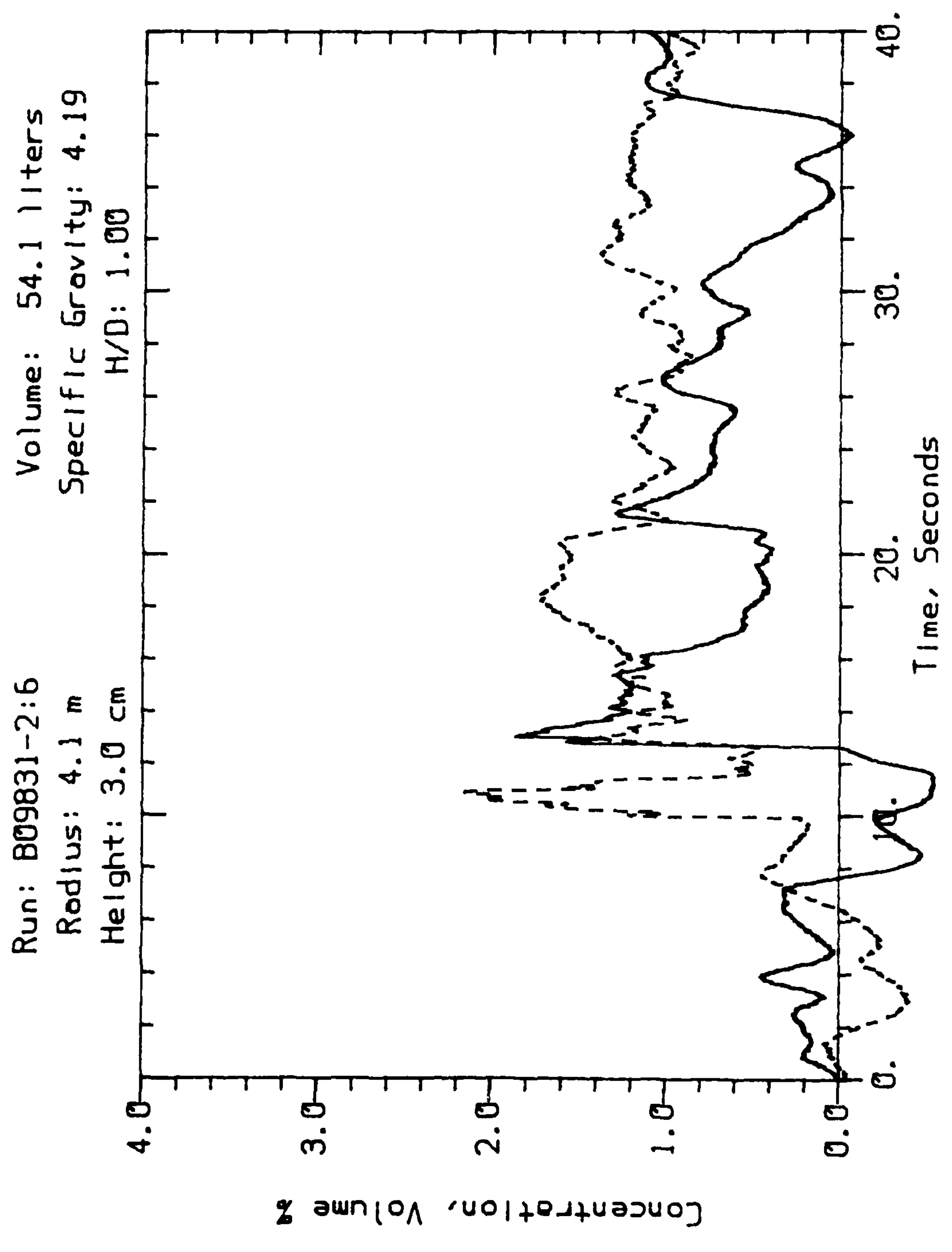
A-28

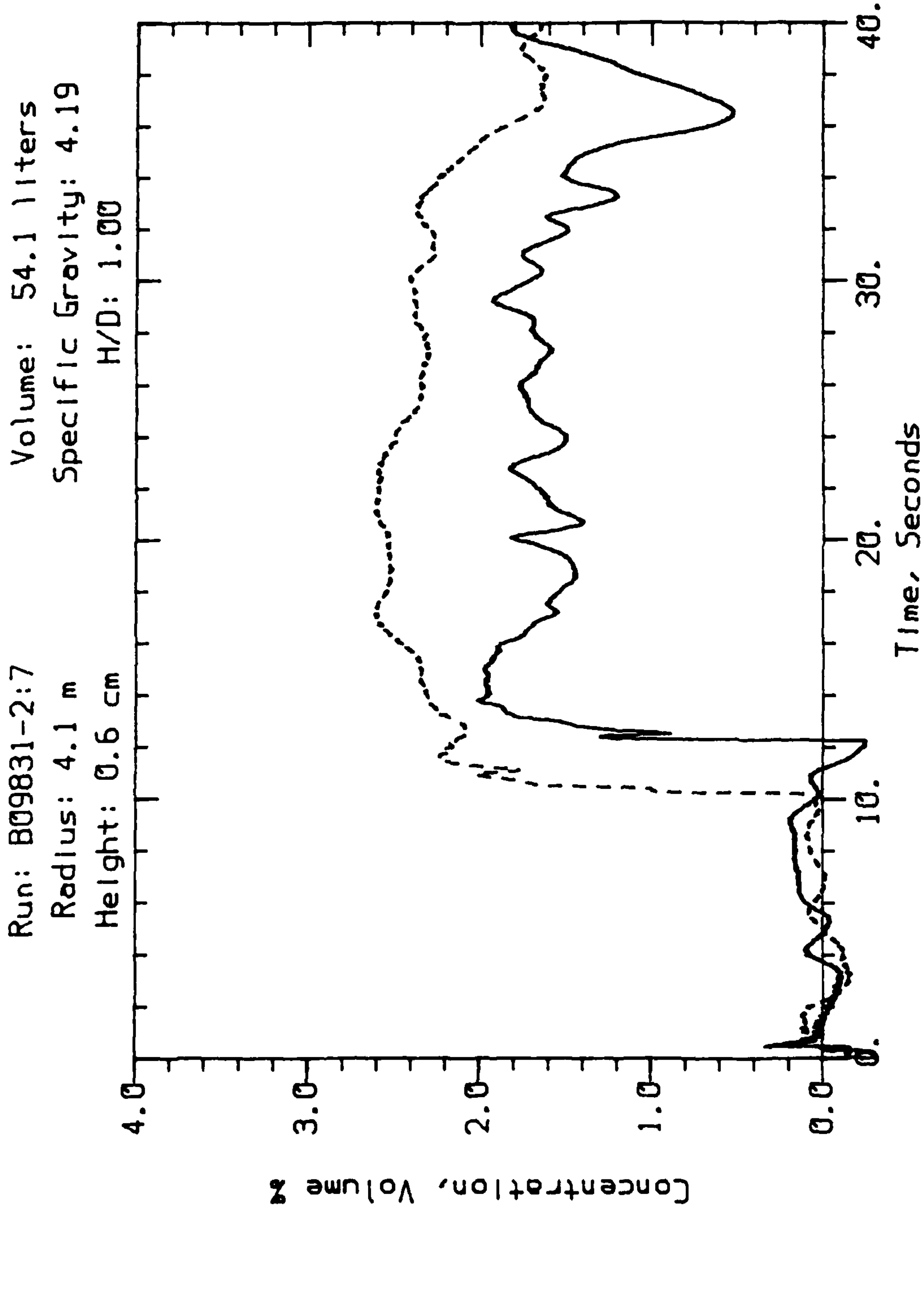


Run: B09831-2:4
Radius: 2.9 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Time, Seconds
Concentration, Volume %
0.
5.
10.
15.
20.

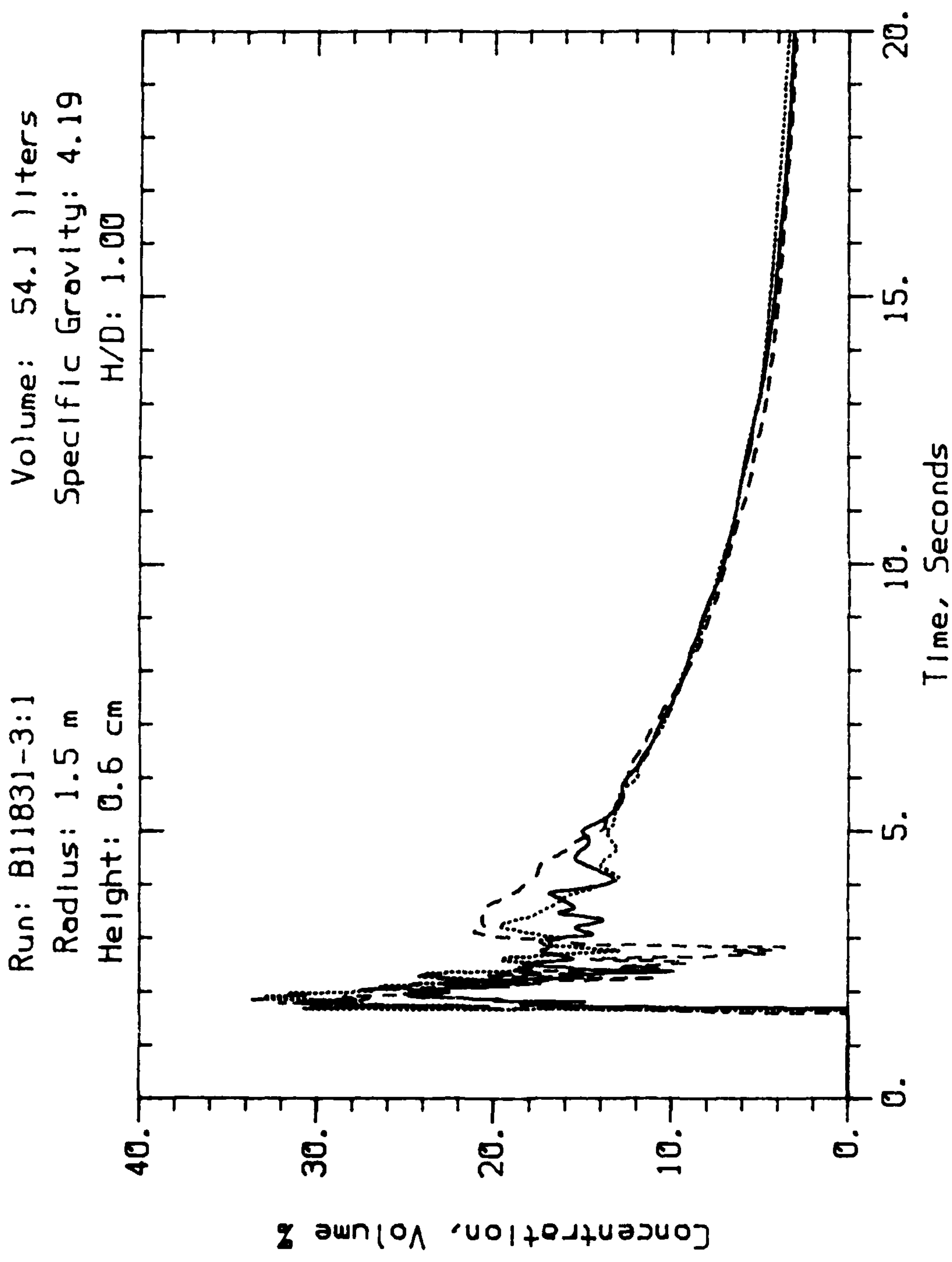


Run: B09831-2:5
Radius: 2.9 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
5.
10.
15.
20.

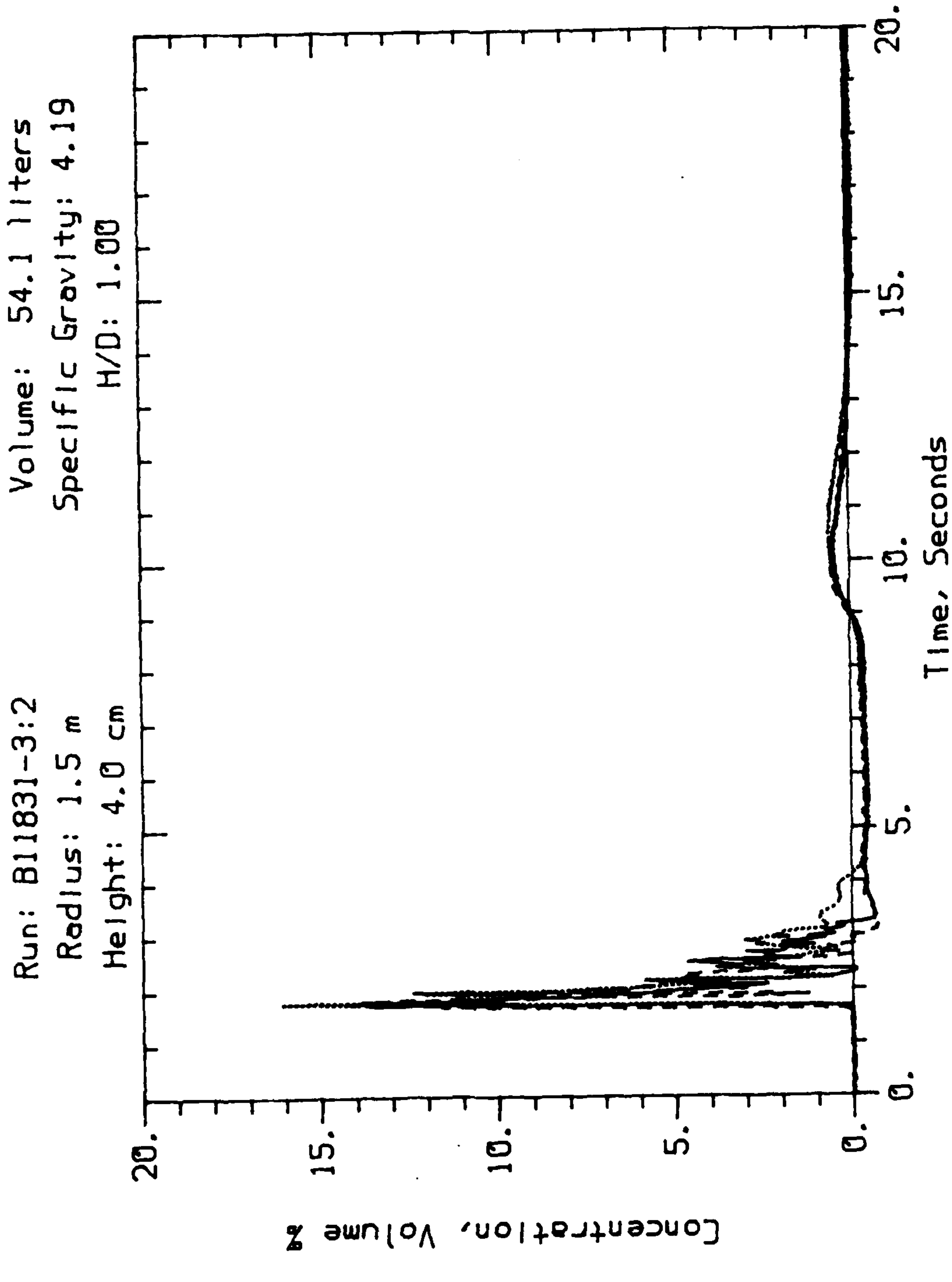

Run: B09831-2:6
Radius: 4.1 m
Height: 3.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
0.
10.
20.
30.
40.
Time, Seconds



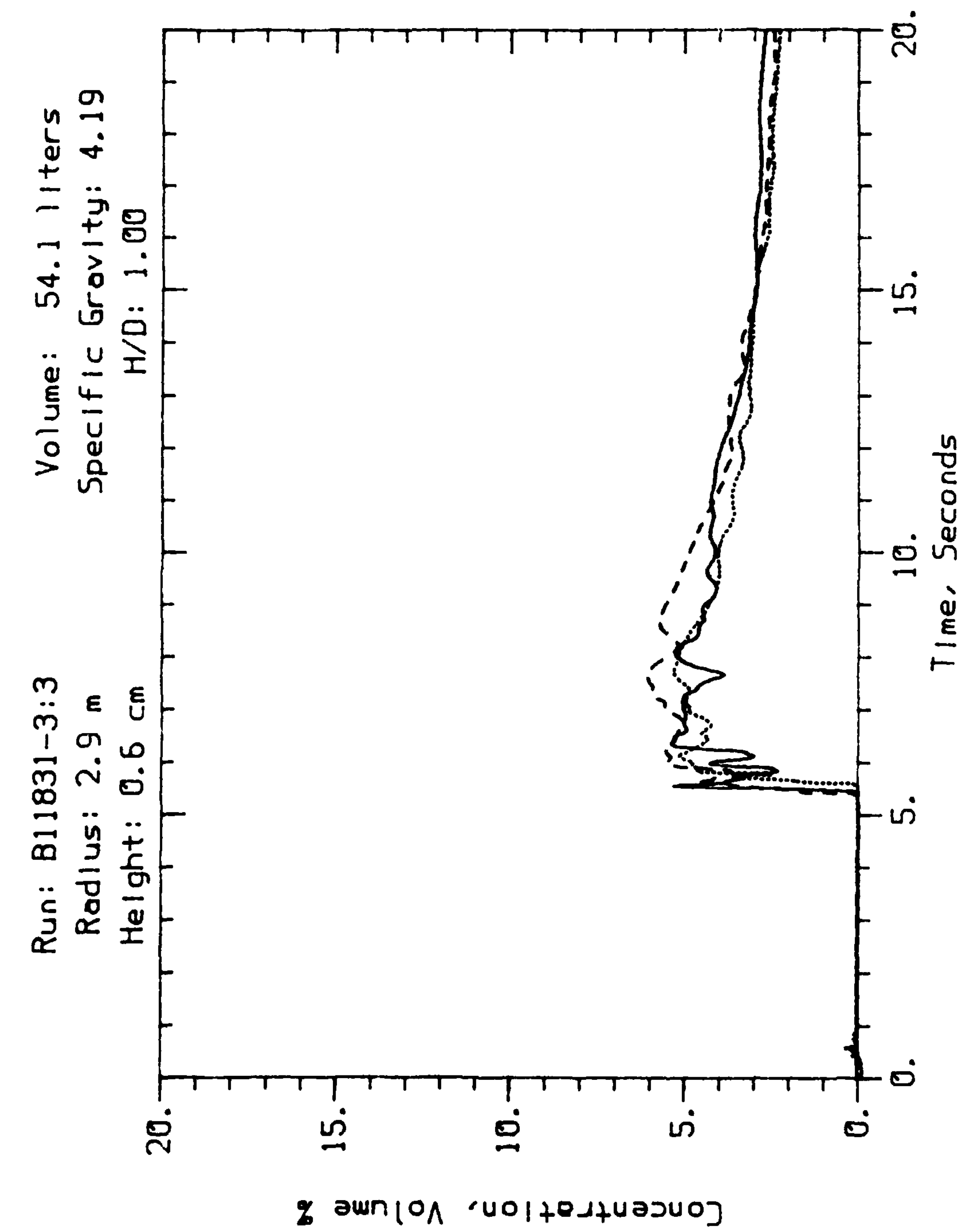
Run: B09831-2:7
Radius: 4.1 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
4.0
3.0
2.0
1.0
0.0
0.
10.
20.
30.
40.
Time, Seconds

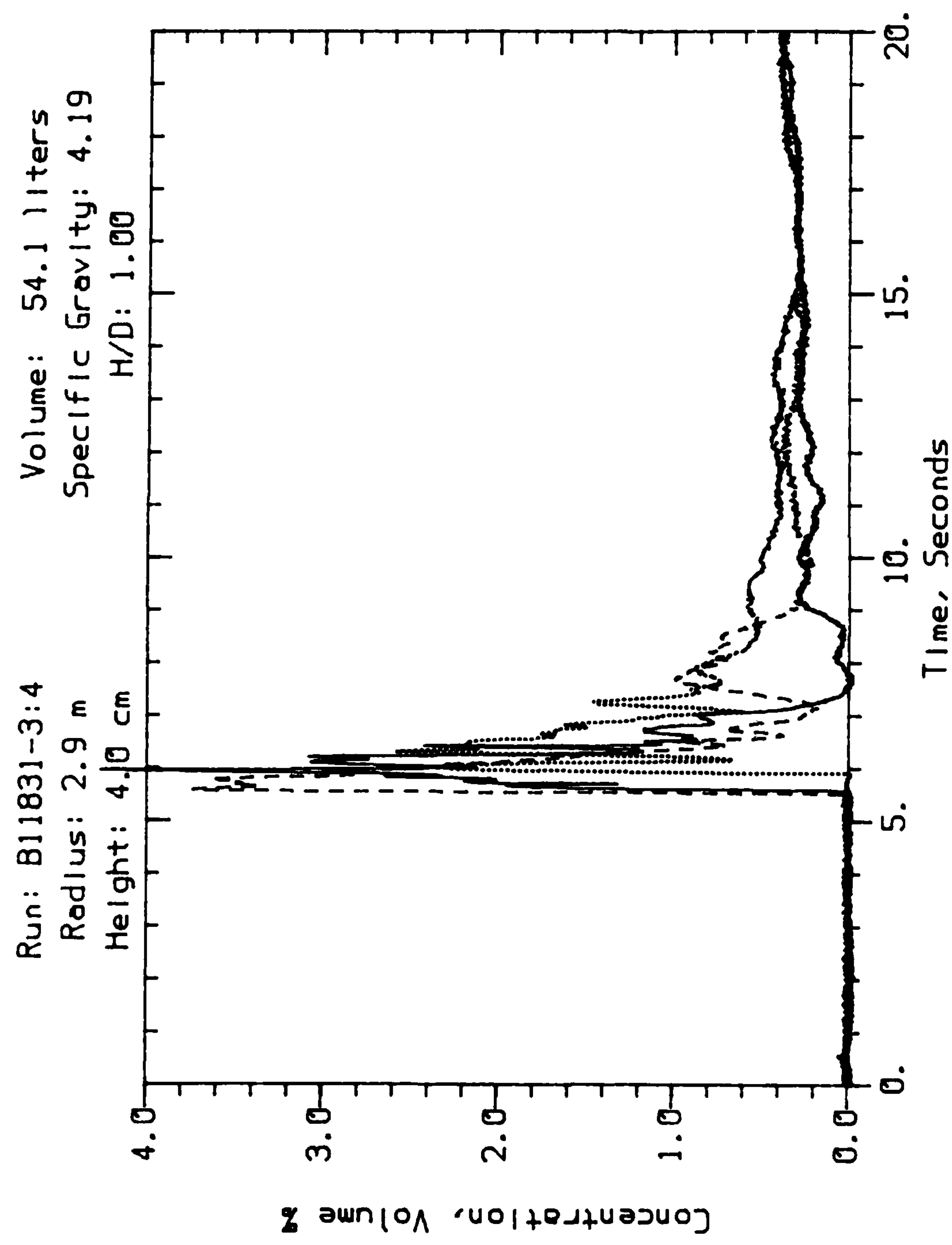


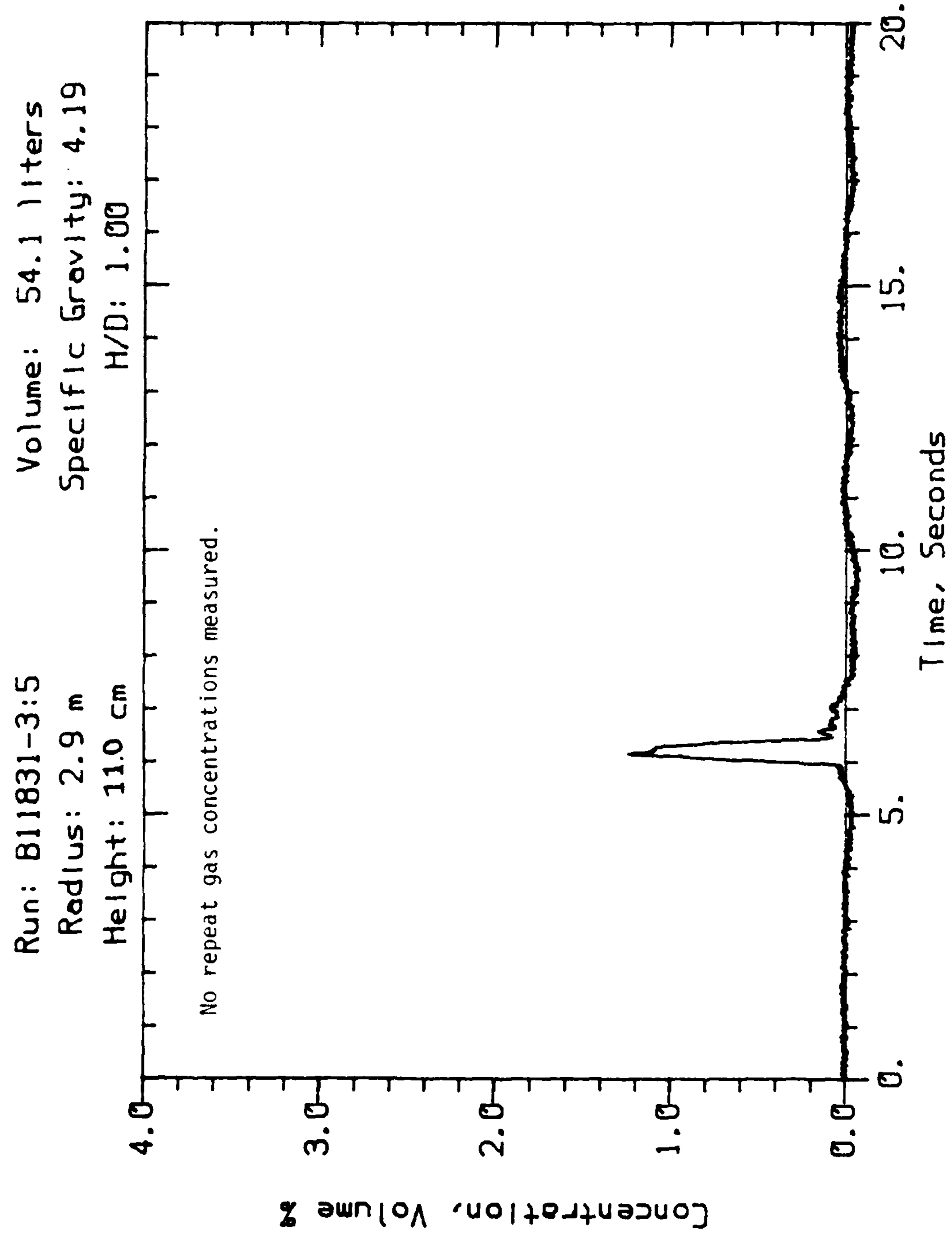
Run: B11831-3:1
Radius: 1.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
10.
20.
30.
40.
0.
5.
10.
15.
20.

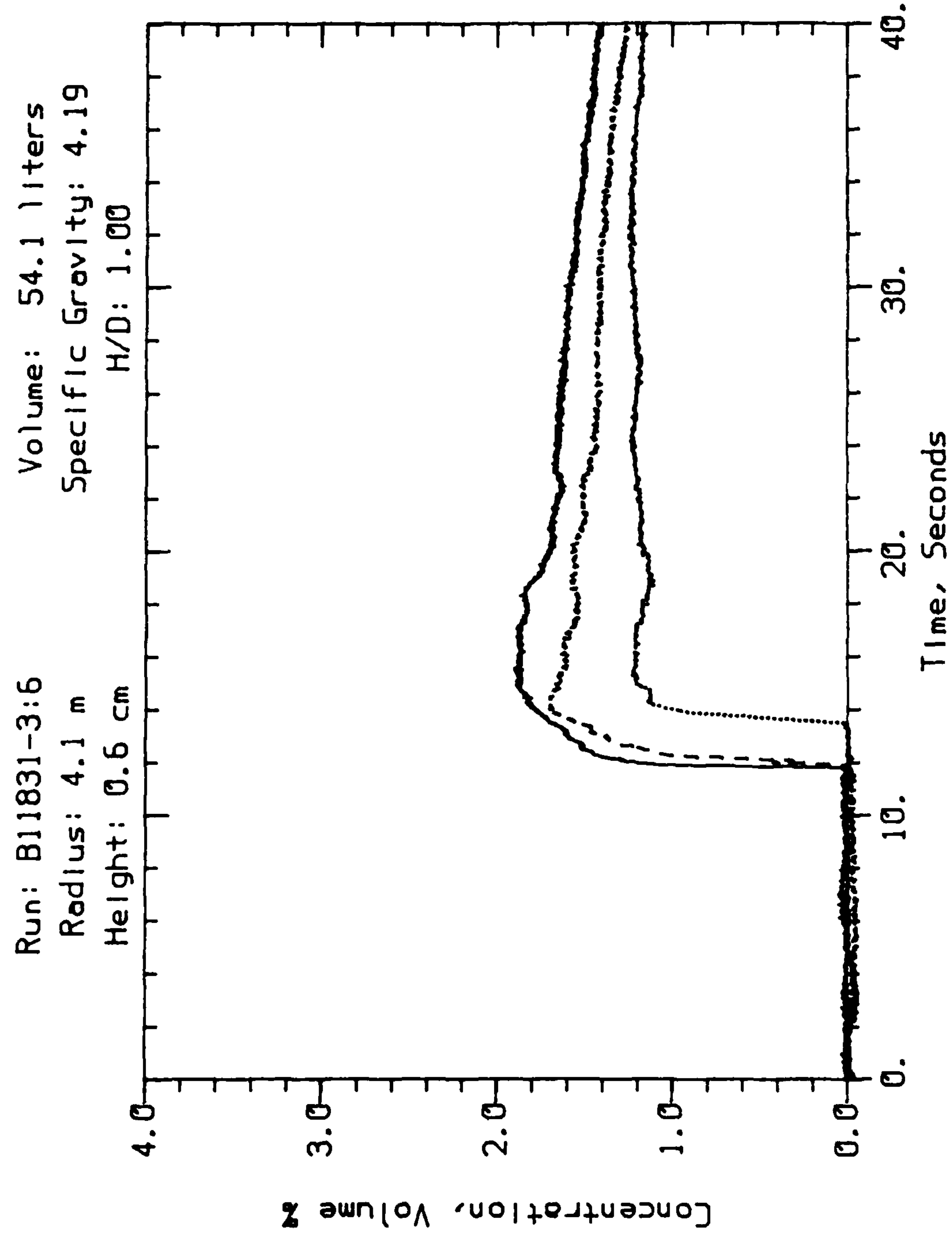


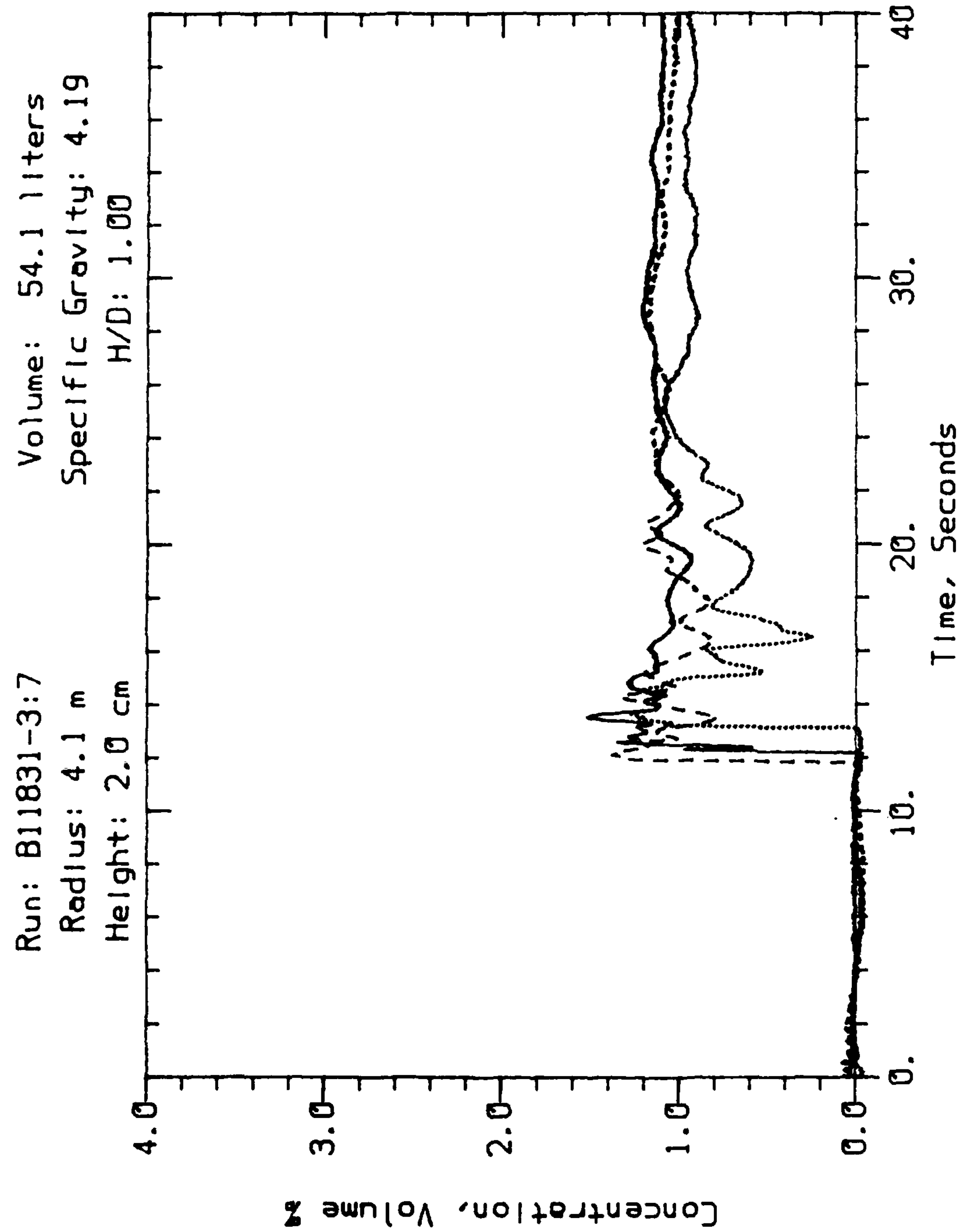
Run: B11831-3:2
Radius: 1.5 m
Height: 4.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Time, Seconds
Concentration, Volume %
0.
5.
10.
15.
20.

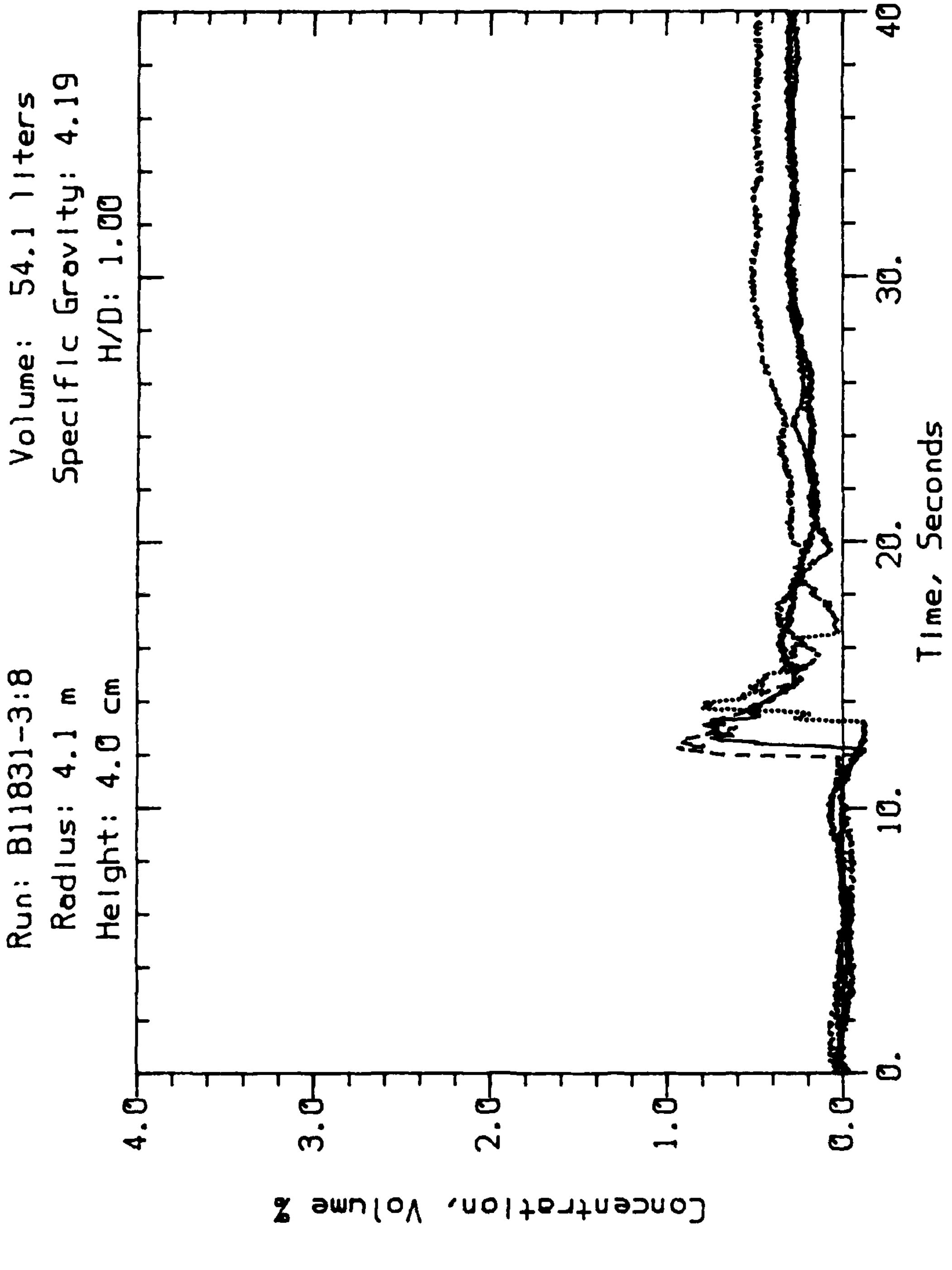

Run: B11831-3:3
Radius: 2.9 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

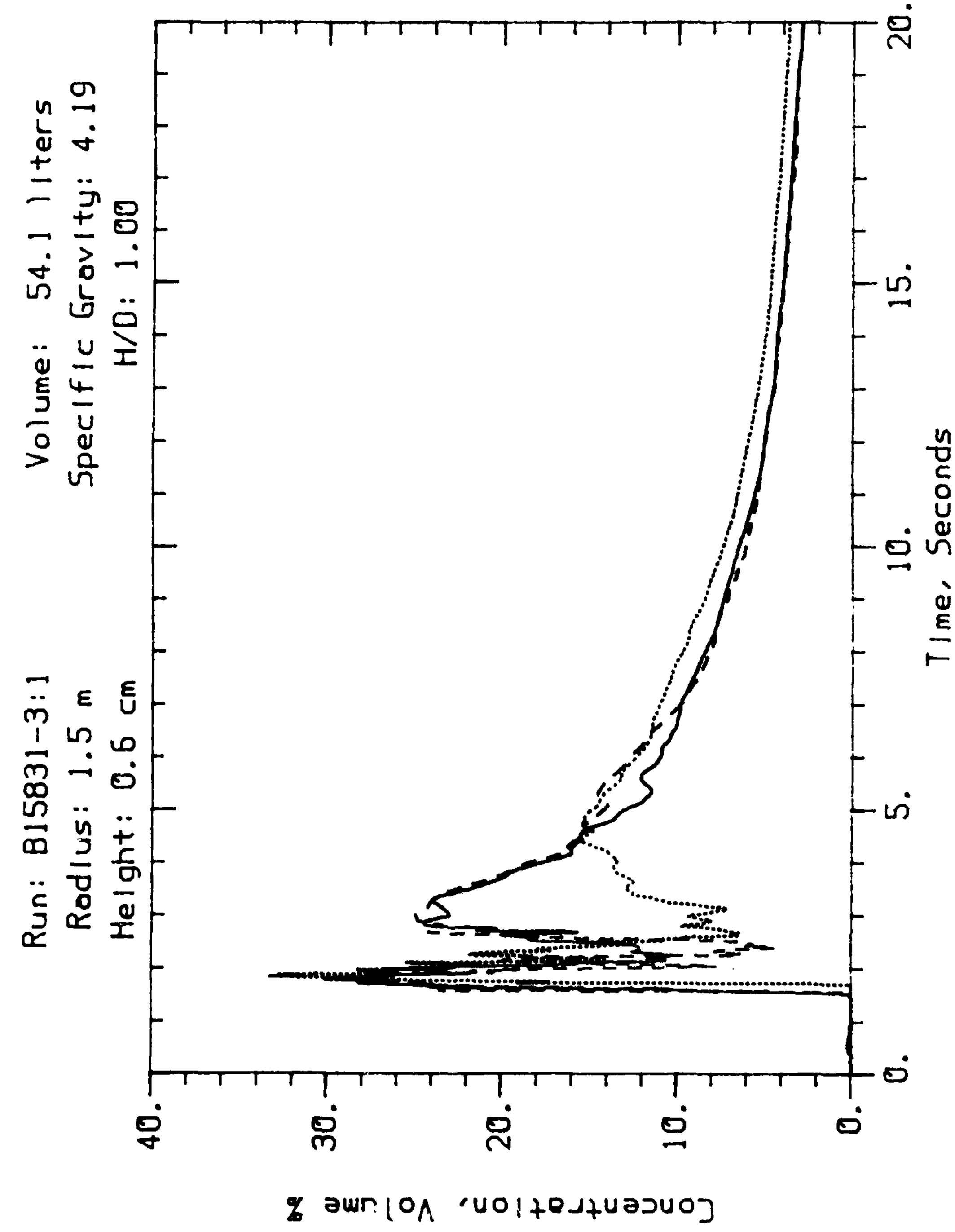

Run: B11831-3:4
Radius: 2.9 m
Height: 4.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.0
1.0
2.0
3.0
4.0
0.
5.
10.
15.
20.


Run: B11831-3:5
Radius: 2.9 m
Height: 11.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
No repeat gas concentrations measured.
Time, Seconds
0.
5.
10.
15.
20.
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0

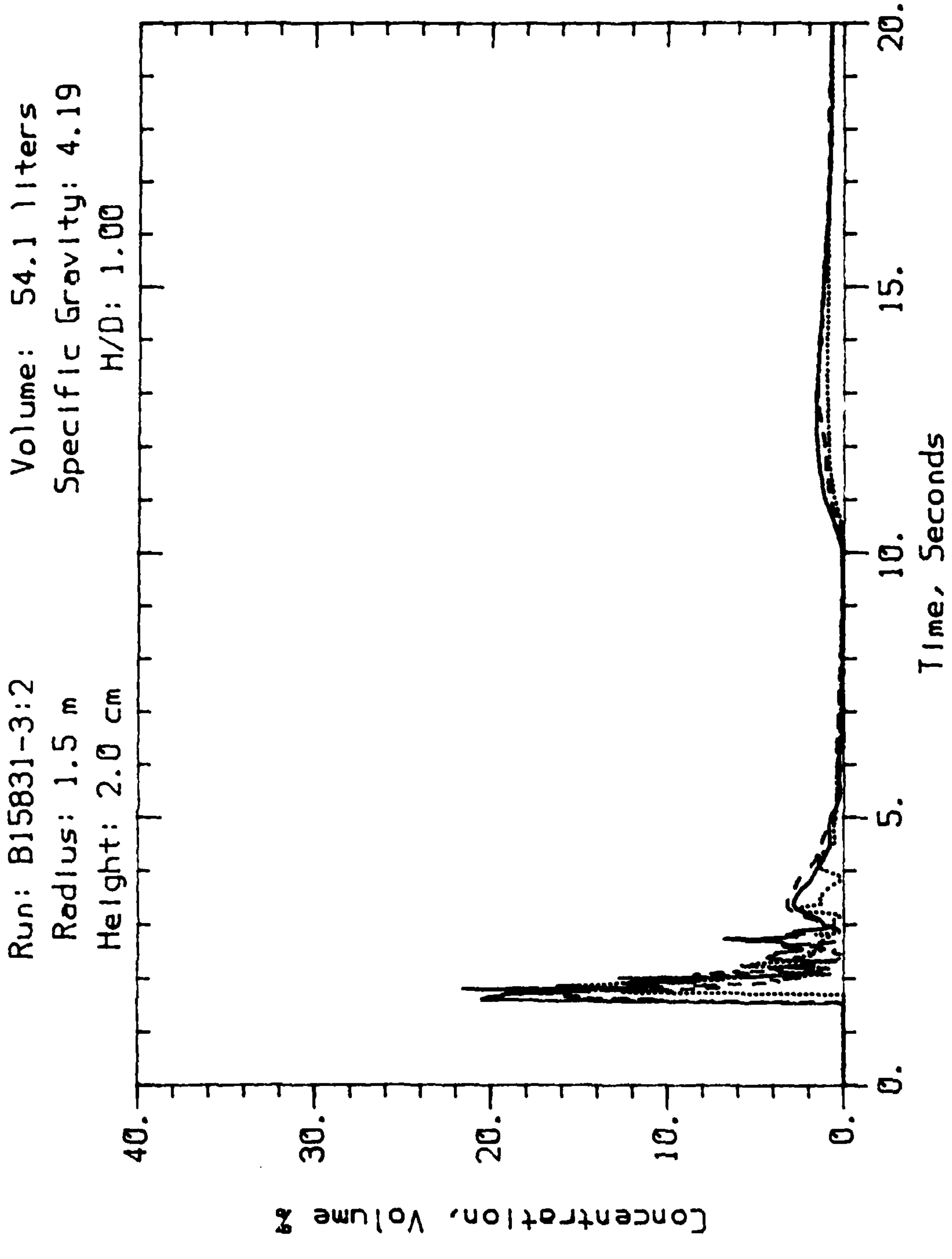

Run: B11831-3:6
Radius: 4.1 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
10.
20.
30.
40.

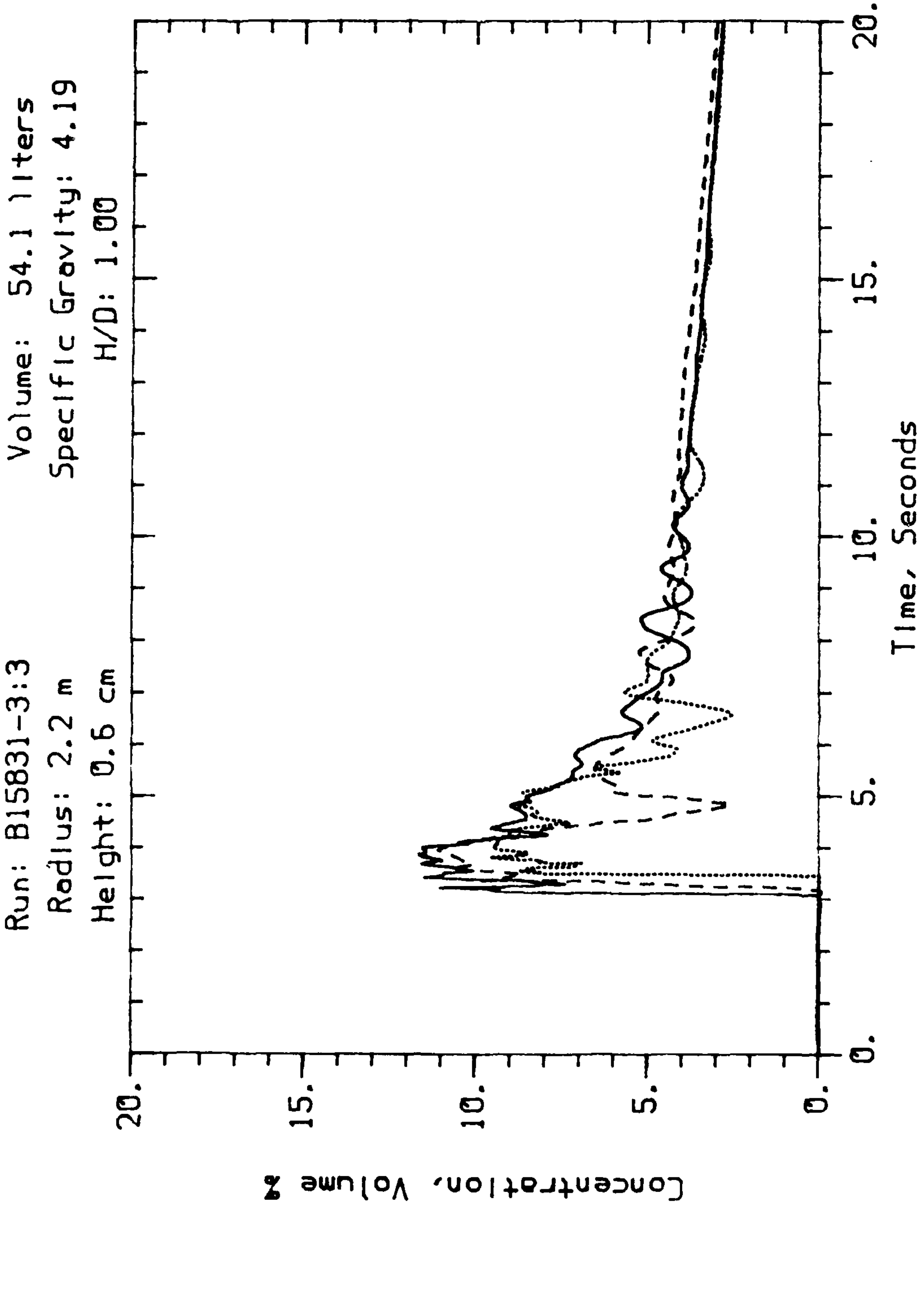

Run: B11831-3:7
Radius: 4.1 m
Height: 2.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
10.
20.
30.
40.


Run: B11831-3:8
Radius: 4.1 m
Height: 4.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
10.
20.
30.
40.

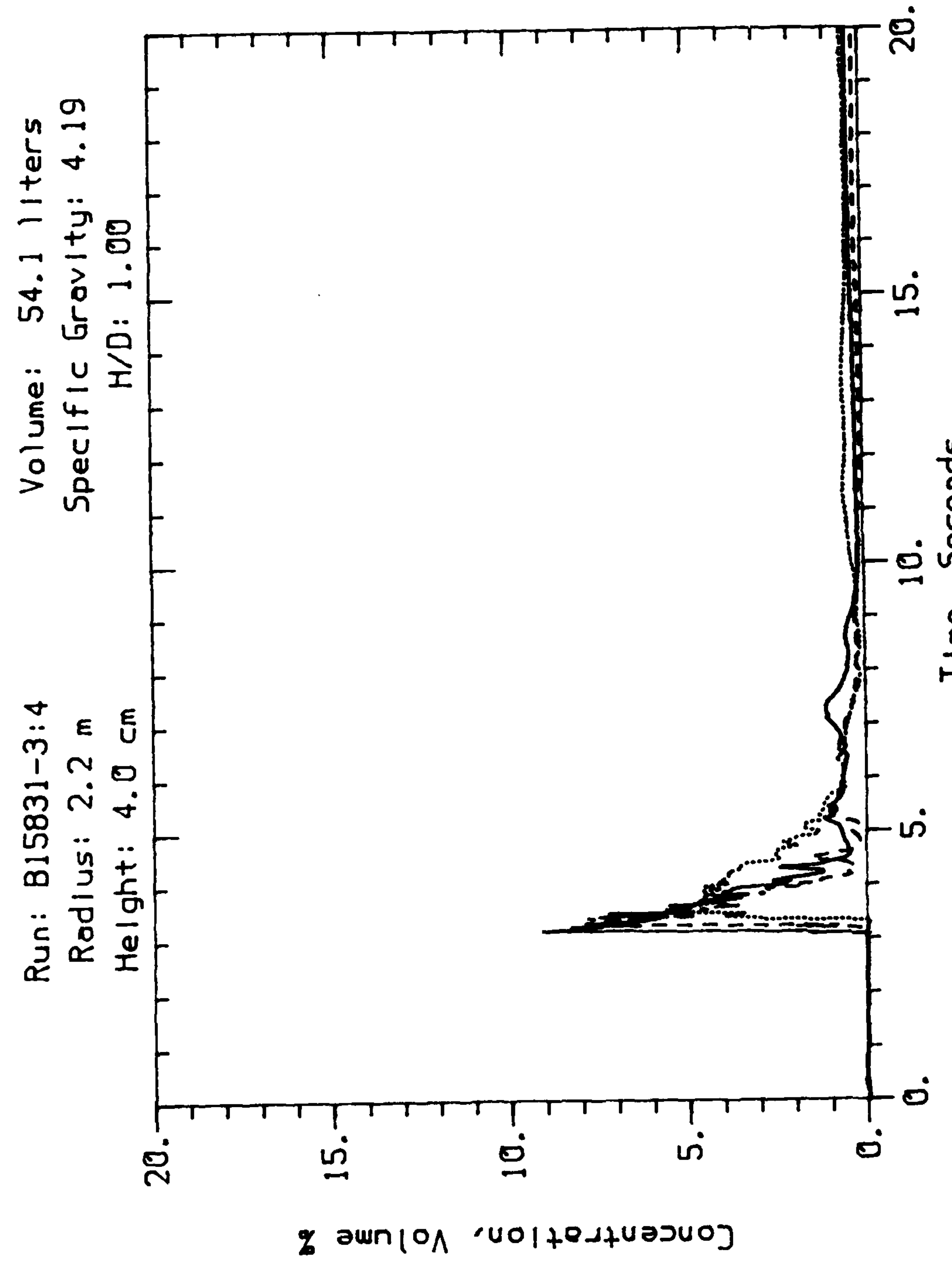


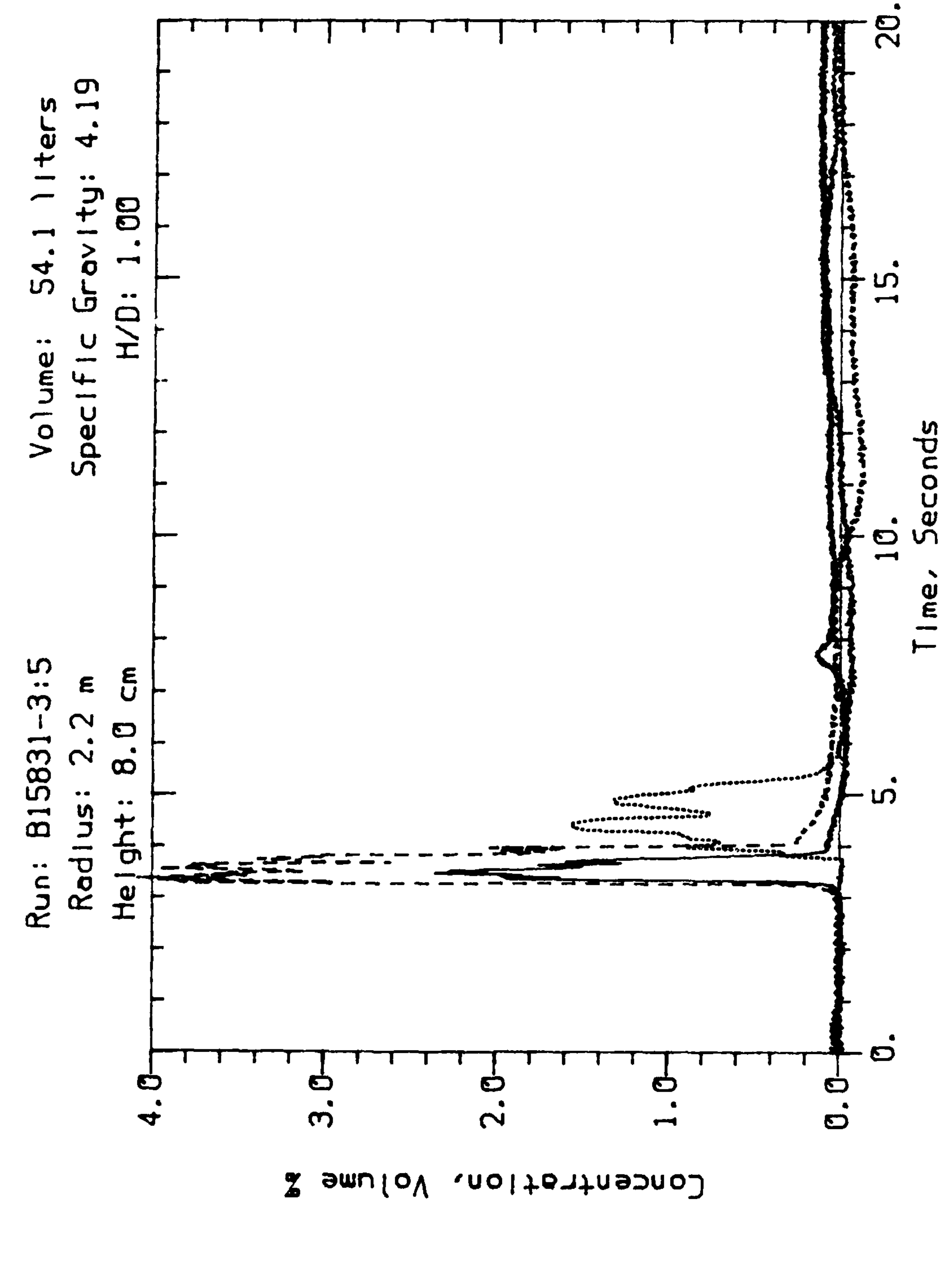
Run: B15831-3:1
Radius: 1.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.
10.
20.
30.
40.
Time, Seconds
0.
5.
10.
15.
20.

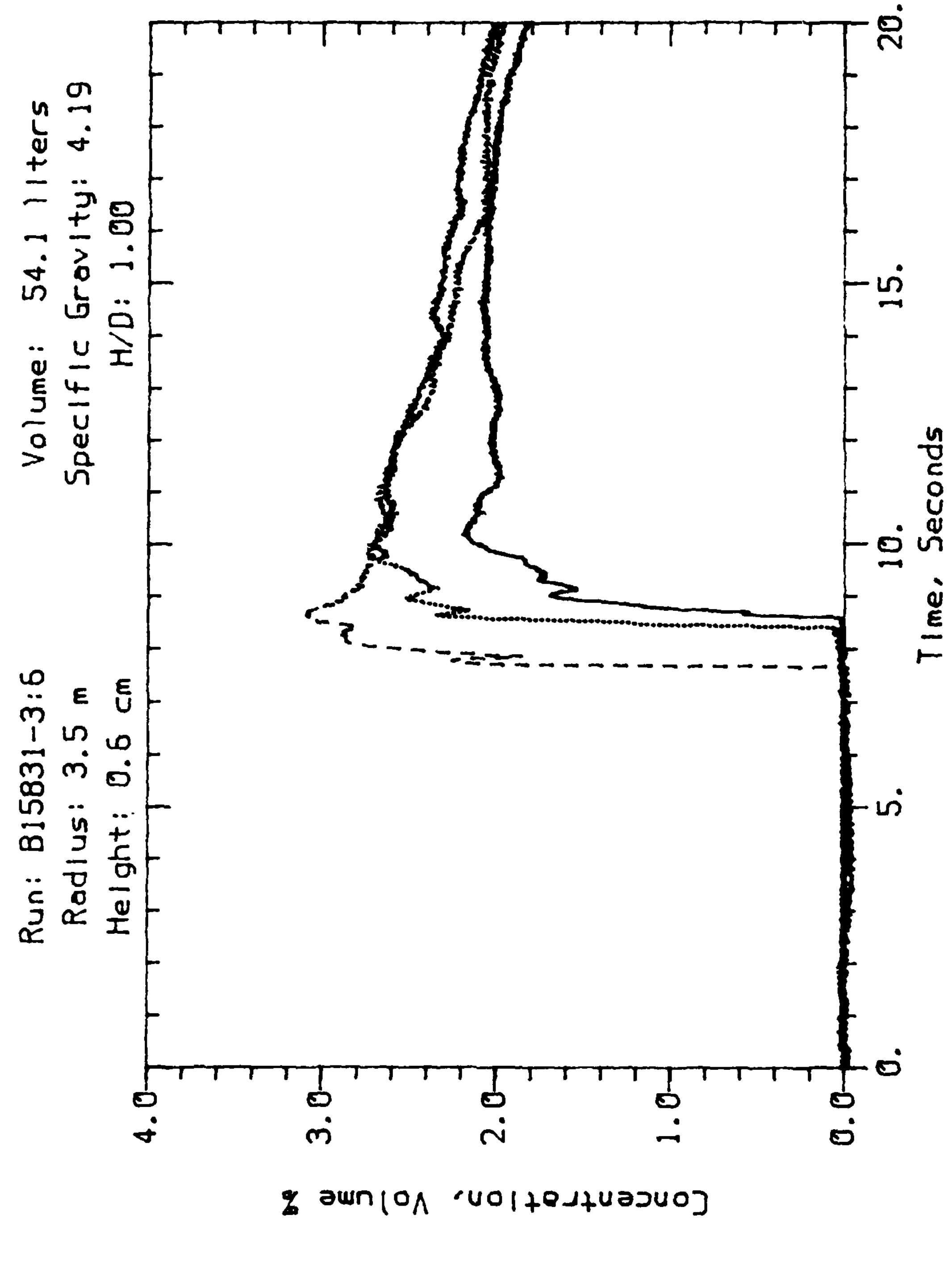

Run: B15831-3:2
Radius: 1.5 m
Height: 2.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
40.
30.
20.
10.
0.
Time, Seconds
0.
5.
10.
15.
20.

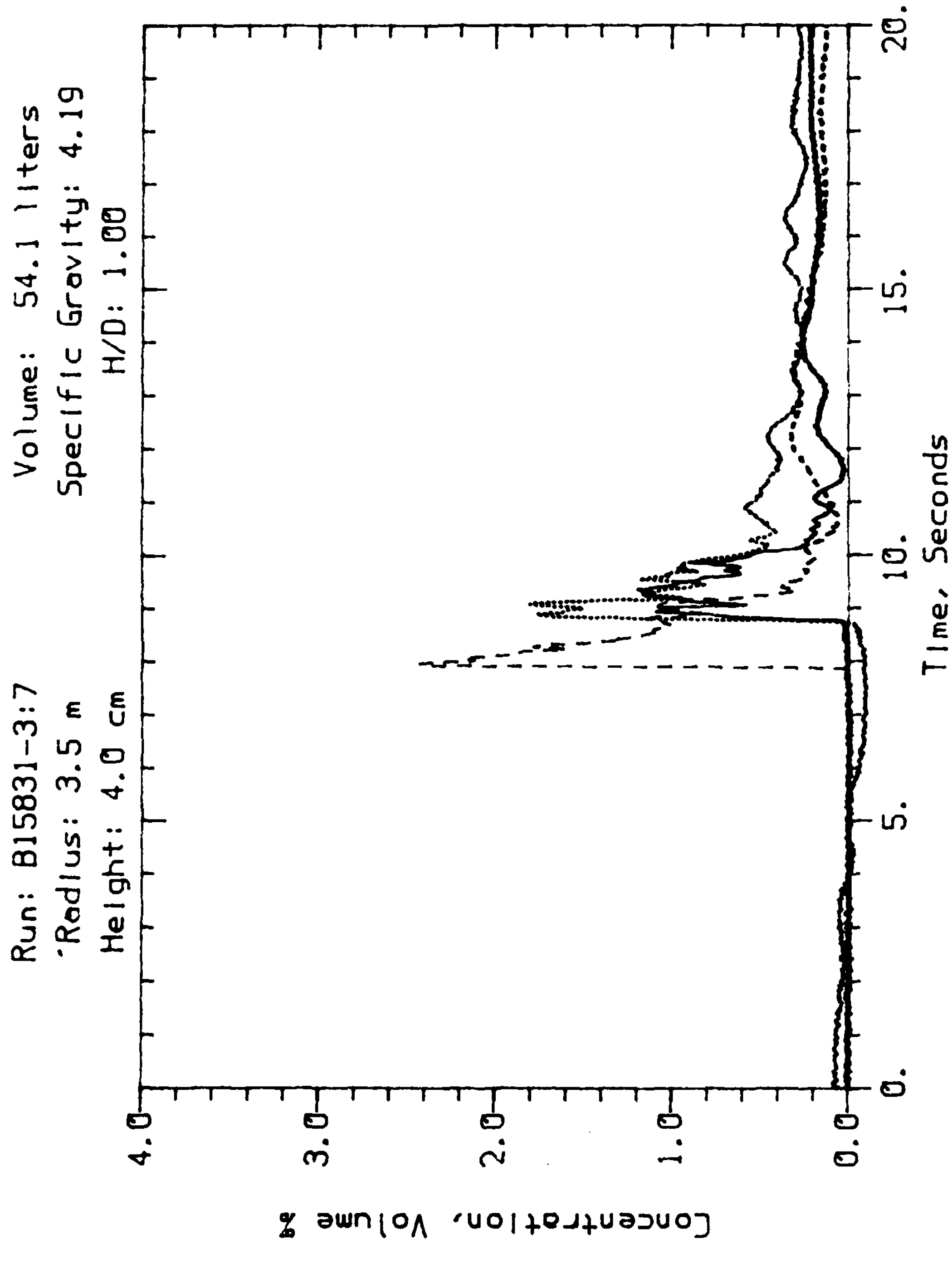


Run: B15831-3:3
Radius: 2.2 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

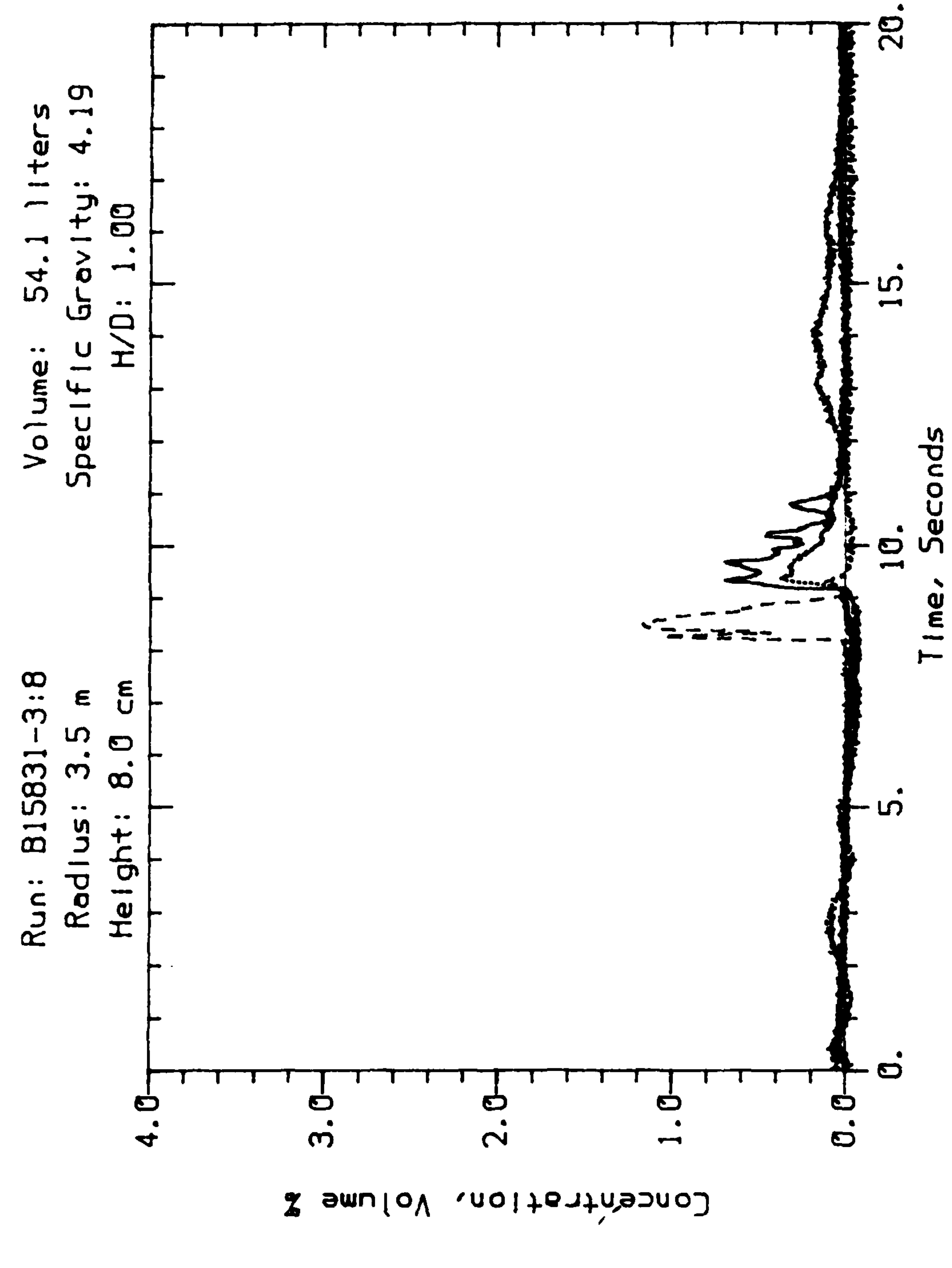

Run: B15831-3:4
Radius: 2.2 m
Height: 4.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.
5.
10.
15.
20.
Concentration, Volume %


Run: B15831-3:5
Radius: 2.2 m
Height: 8.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
4.0
3.0
2.0
1.0
0.0
0.
5.
10.
15.
20.
Time, Seconds

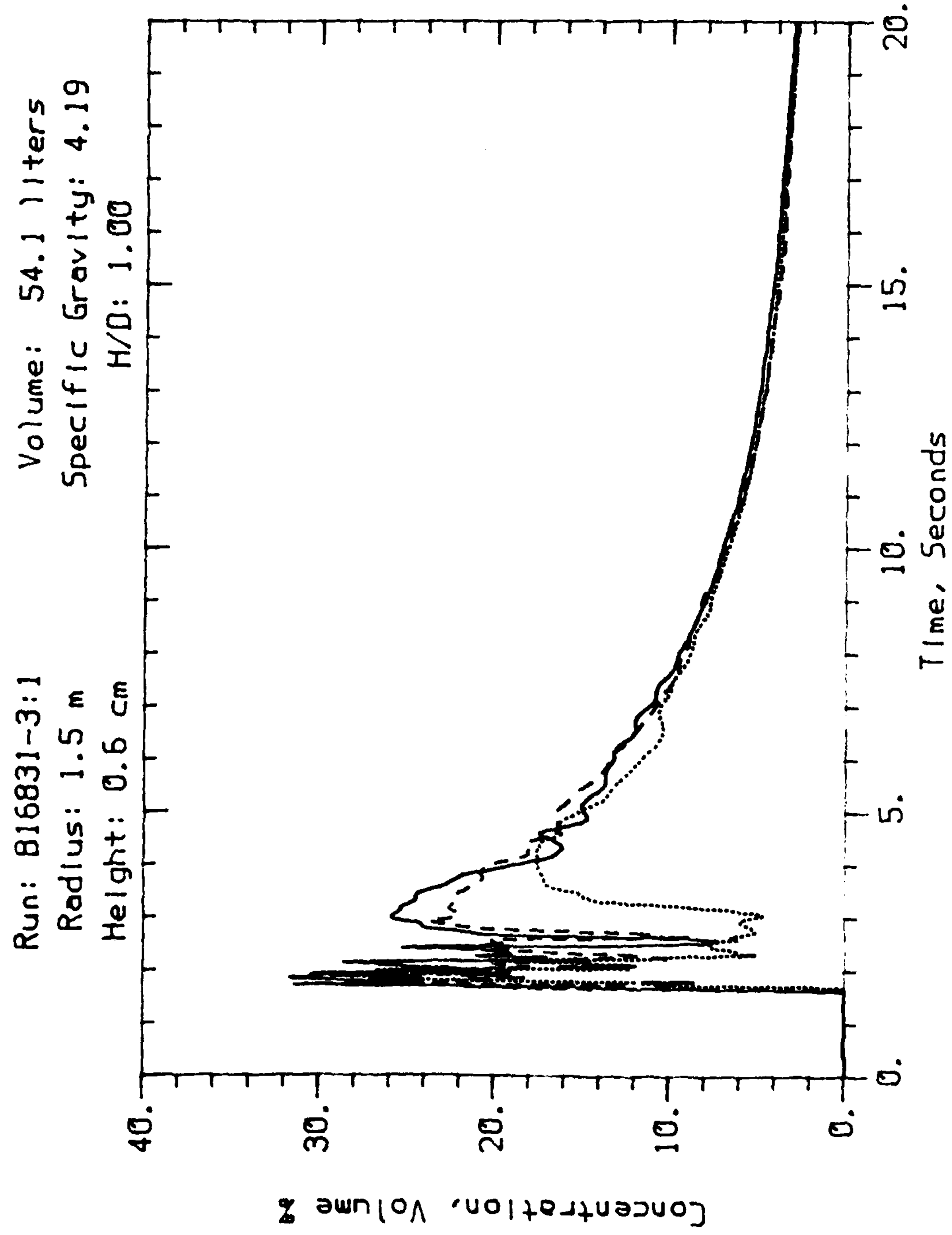

Run: B15831-3:6
Radius: 3.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.0
1.0
2.0
3.0
4.0
Concentration, Volume %



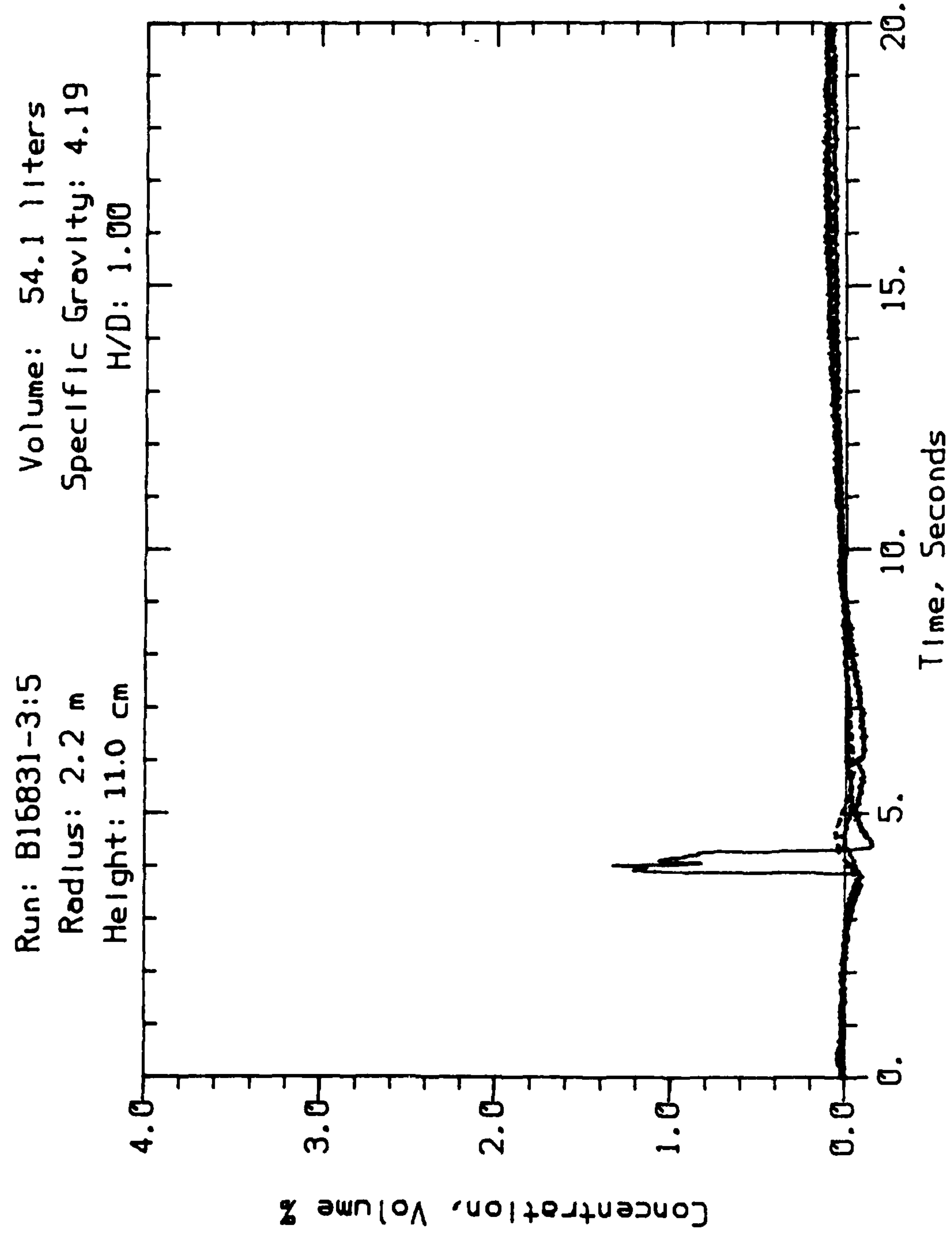
Run: B15831-3:7
Radius: 3.5 m
Height: 4.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.0
1.0
2.0
3.0
4.0
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

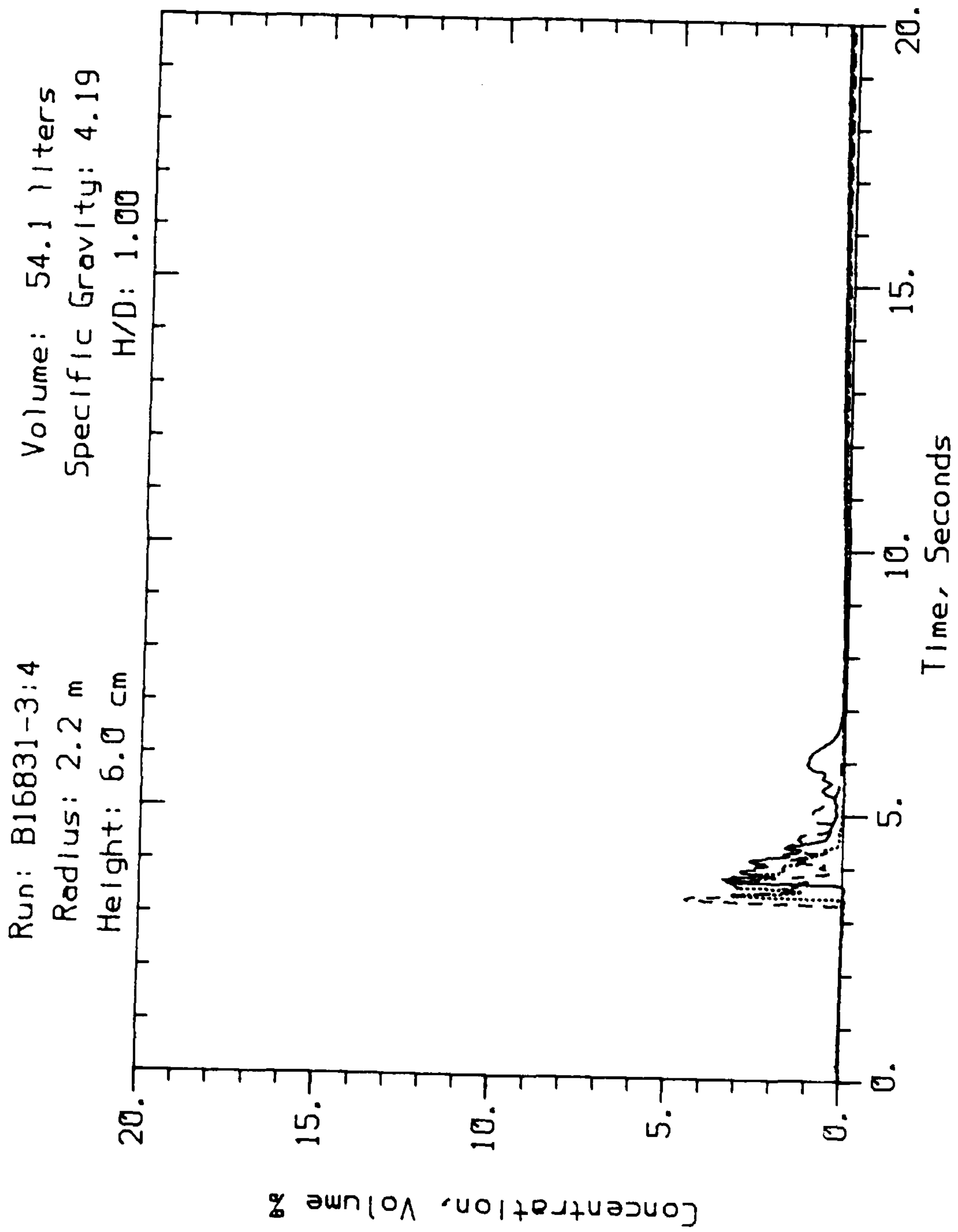


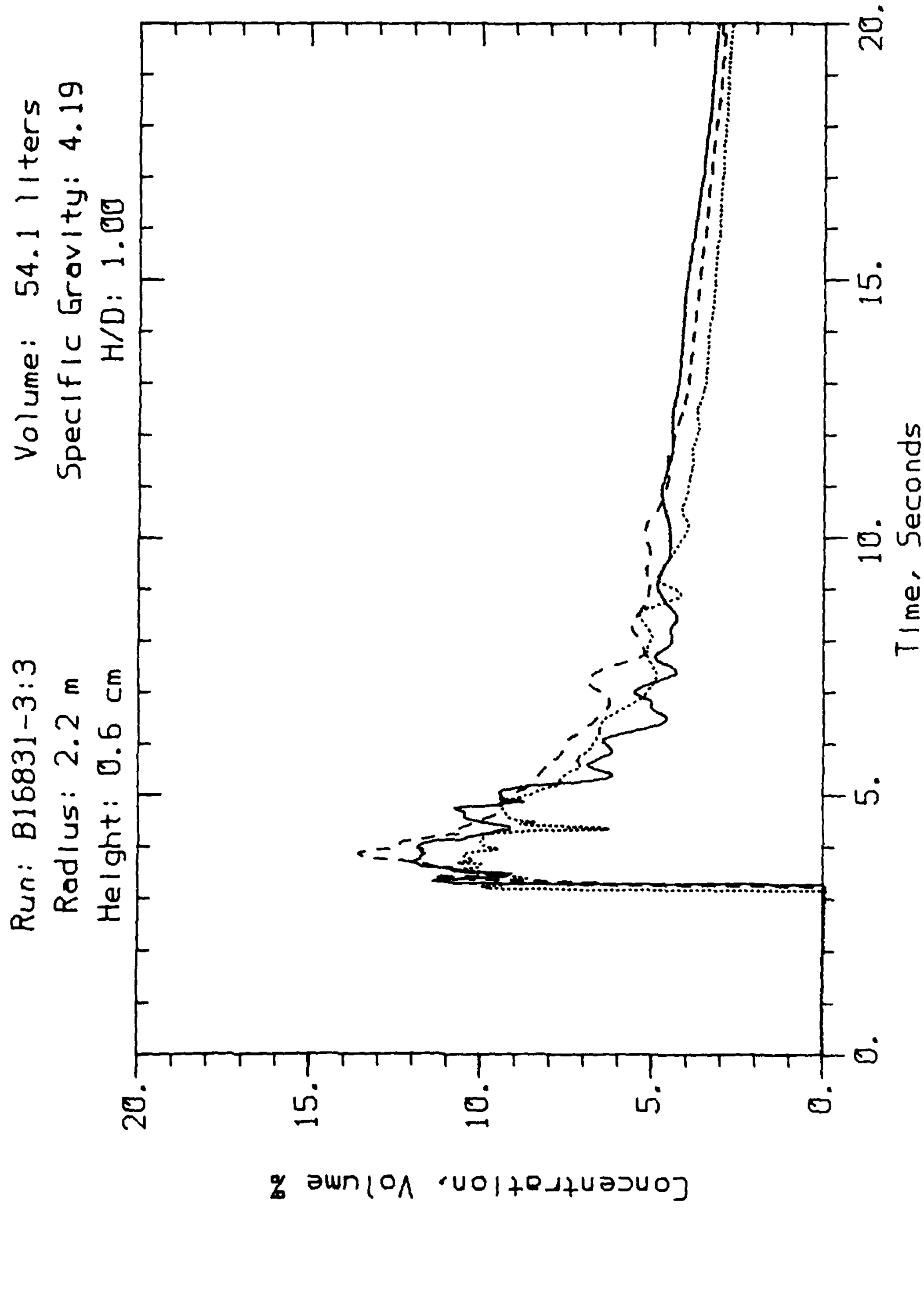
Run: B15831-3:8
Radius: 3.5 m
Height: 8.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.0
1.0
2.0
3.0
4.0
Concentration, Volume %

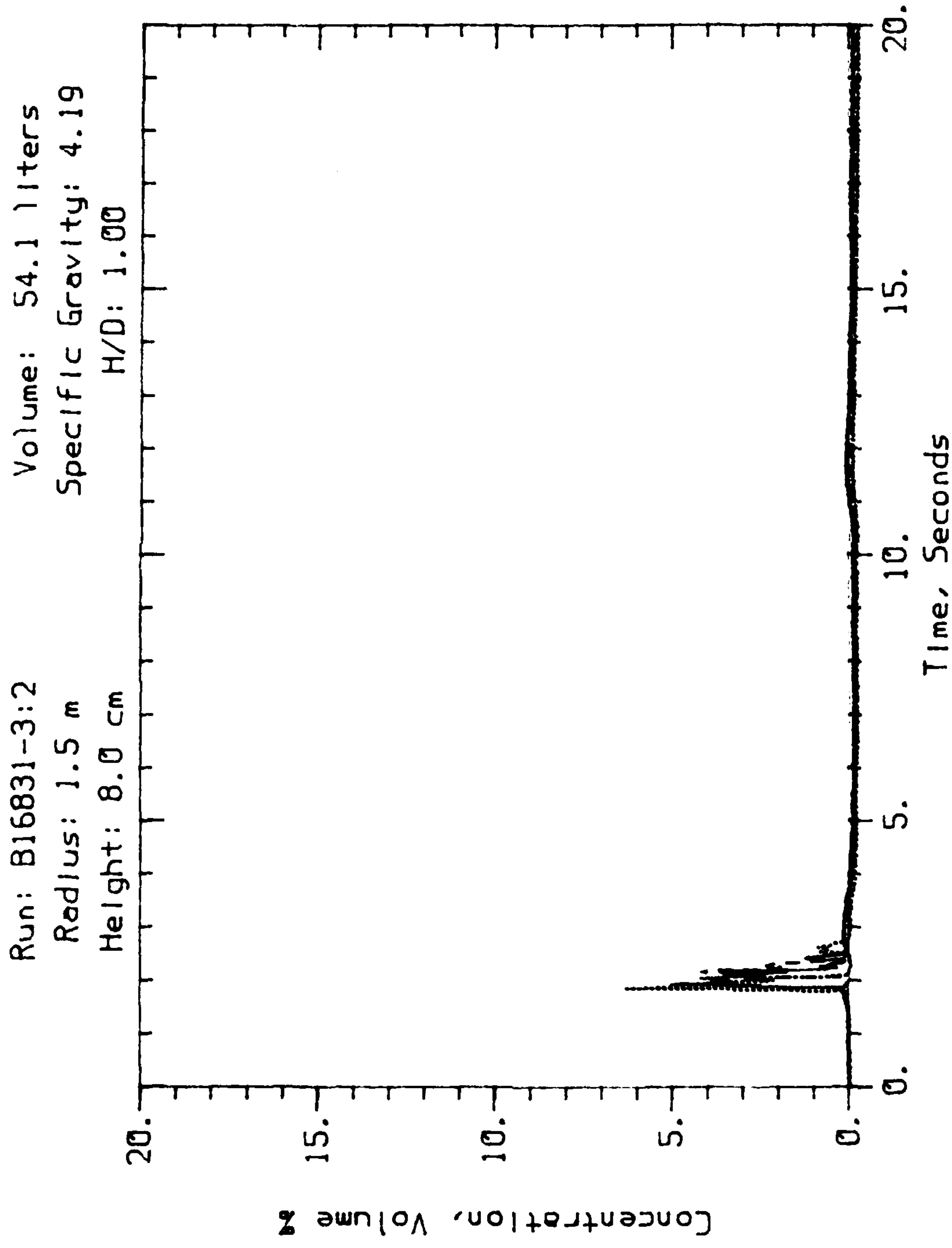


Run: B16831-3:1
Radius: 1.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
40.
30.
20.
10.
0.
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

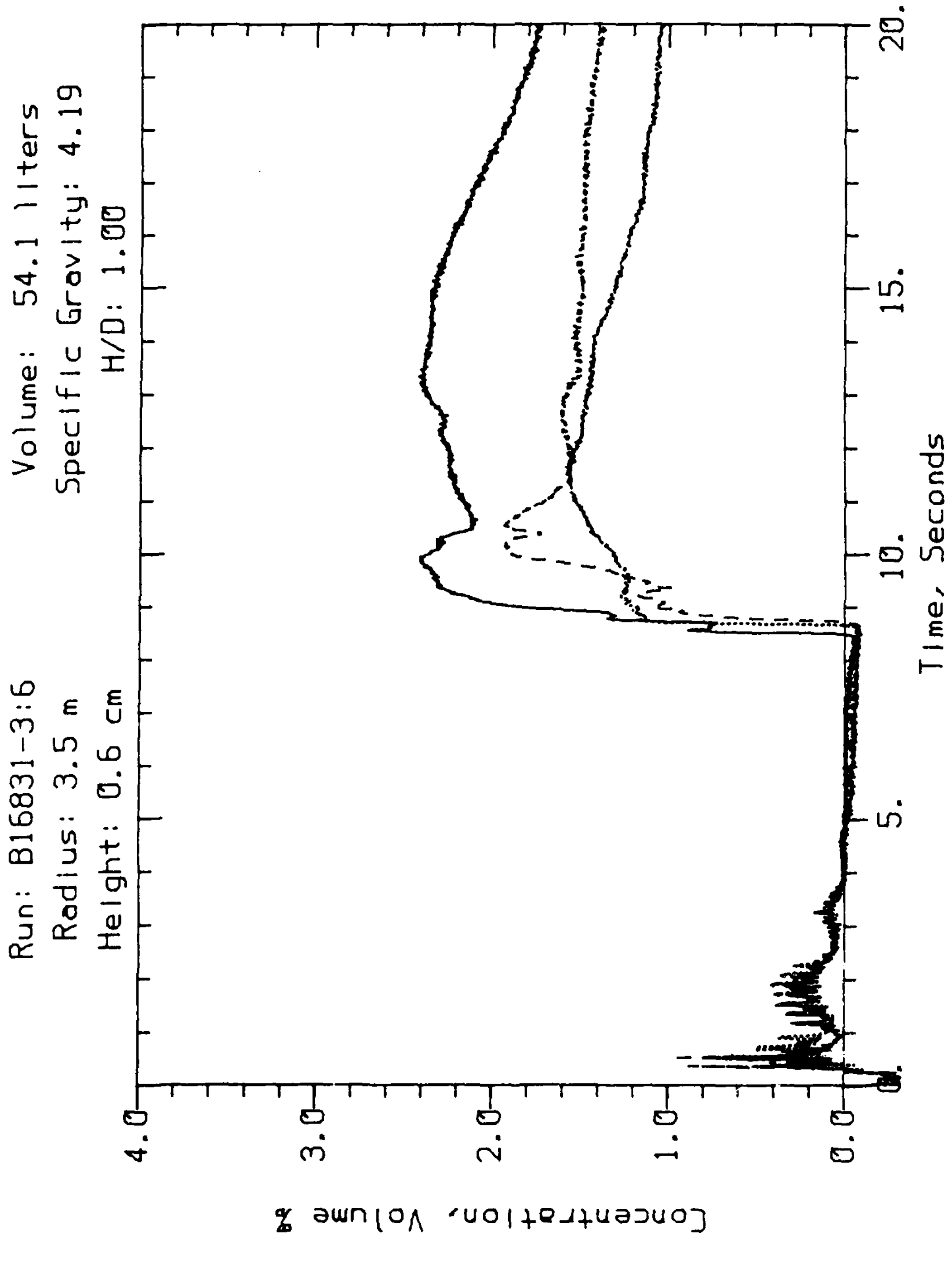

Run: B16831-3:5
Radius: 2.2 m
Height: 11.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
5.
10.
15.
20.


Run: B16831-3:4
Radius: 2.2 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
5.
10.
15.
20.


Run: B16831-3:3
Radius: 2.2 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
5.
10.
15.
20.



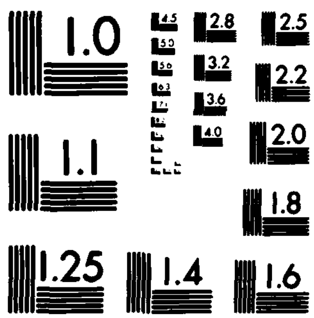
Run: B16831-3:2
Radius: 1.5 m
Height: 8.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.
5.
10.
15.
20.
Concentration, Volume %

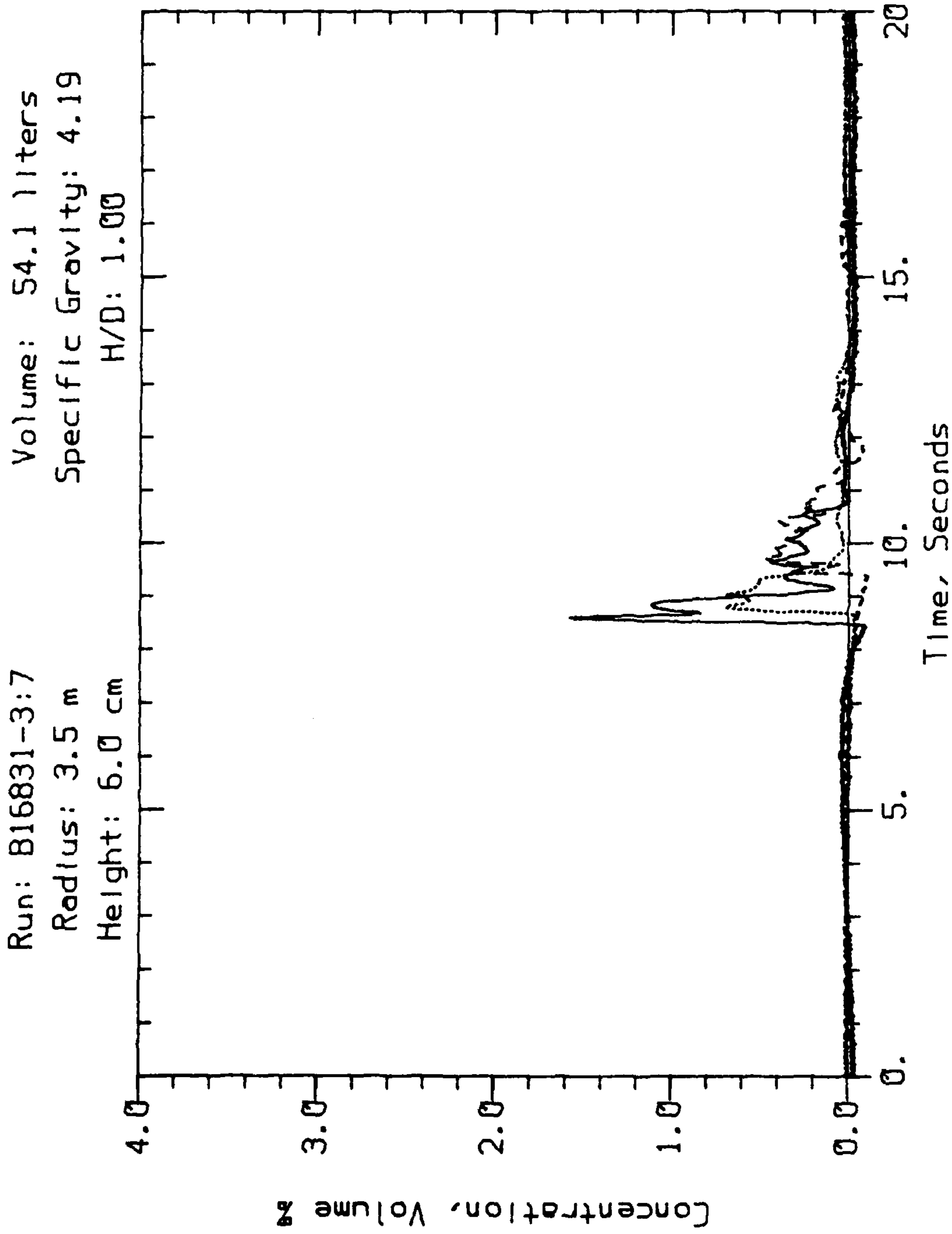

Run: B16831-3:6
Radius: 3.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
5.
10.
15.
20.

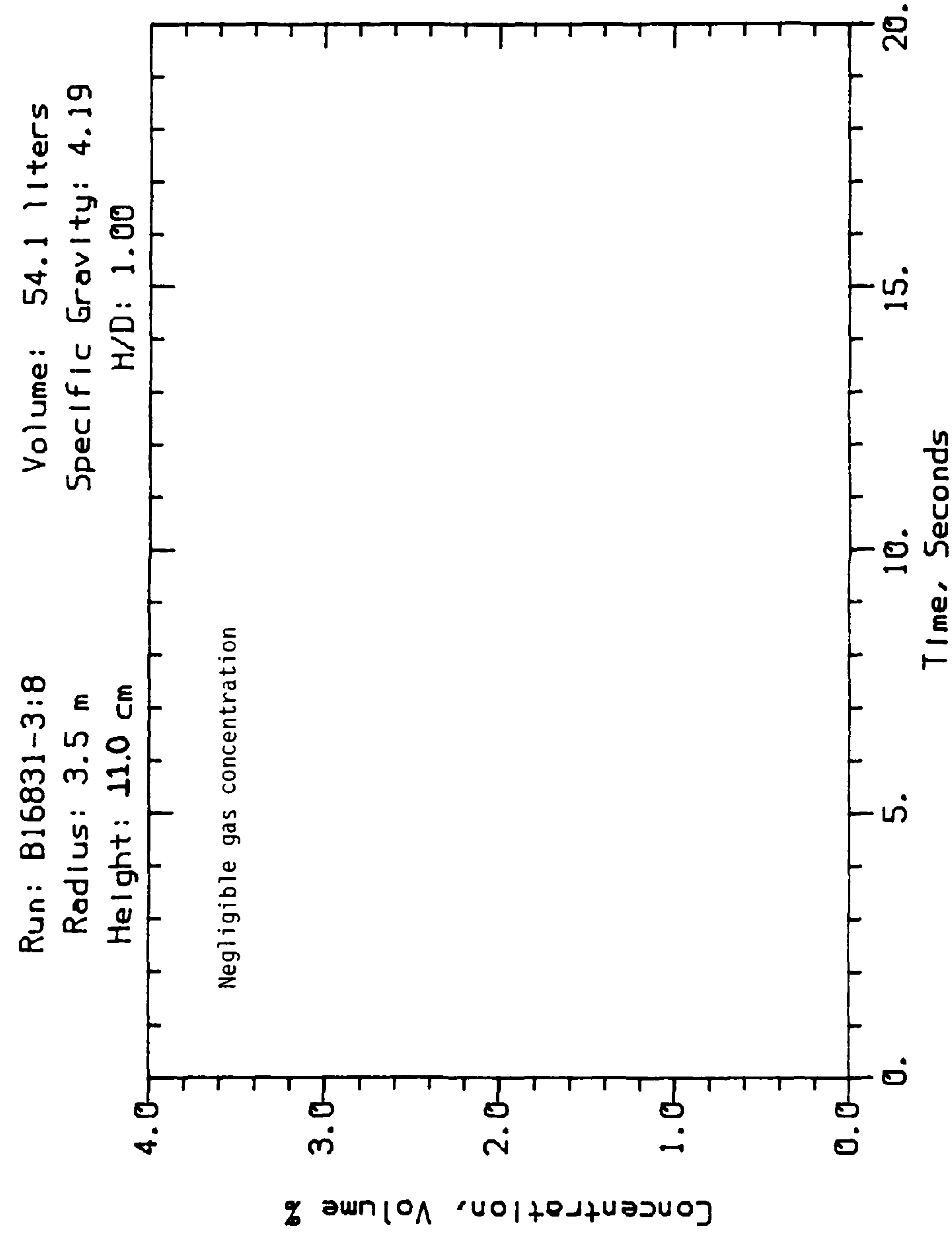
AD-A171 523 DEVELOPMENT OF AN ATMOSPHERIC DISPERSION MODEL FOR HEAVIER-THAN-AIR GAS M..(U) ARKANSAS UNIV FAYETTEVILLE DEPT OF CHEMICAL ENGINEERING J A HAVENS ET AL. MAY 85

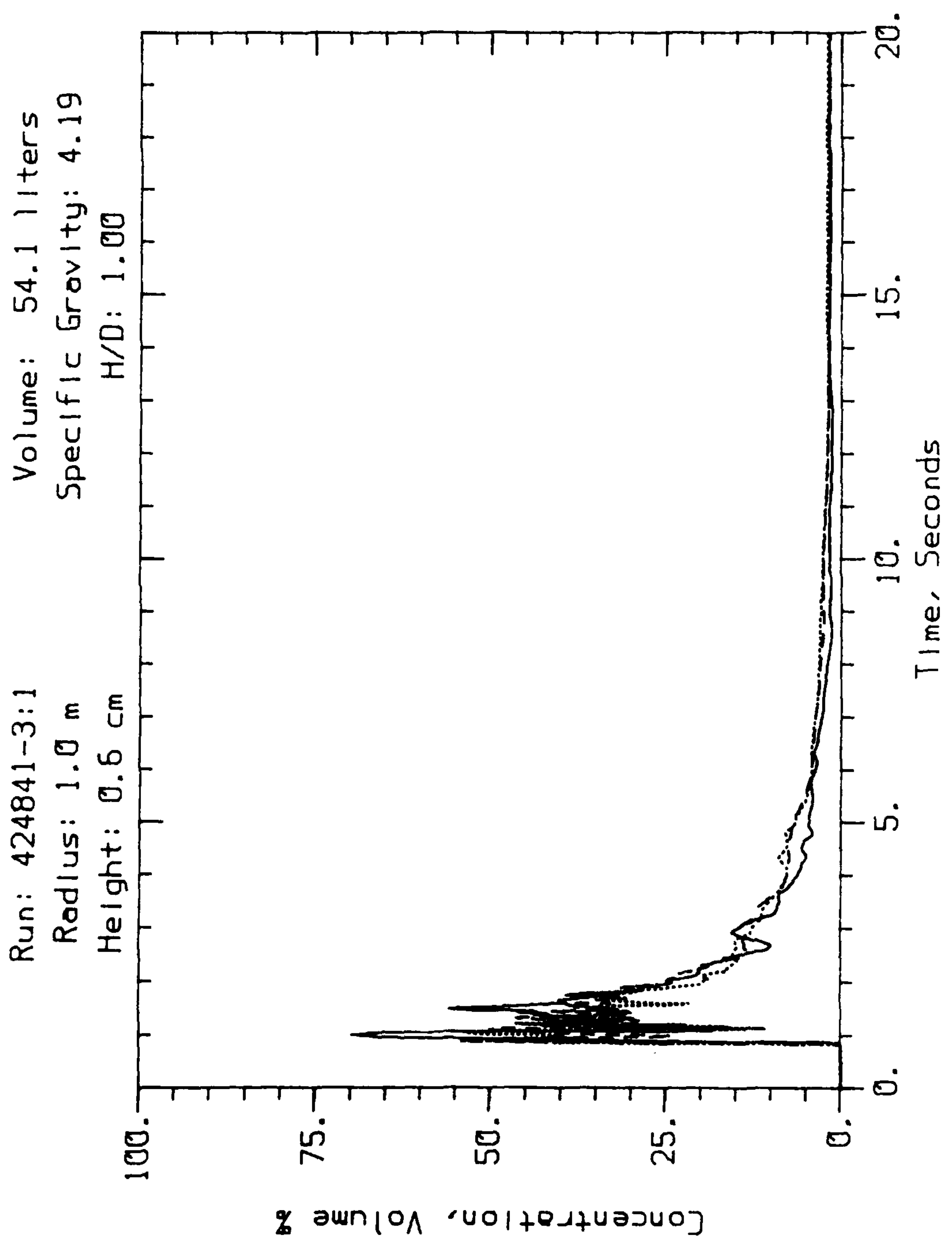
2/3

UNCLASSIFIED USCG-D-23-85 DTCG23-80-C-20029 F/G 20/4 NL

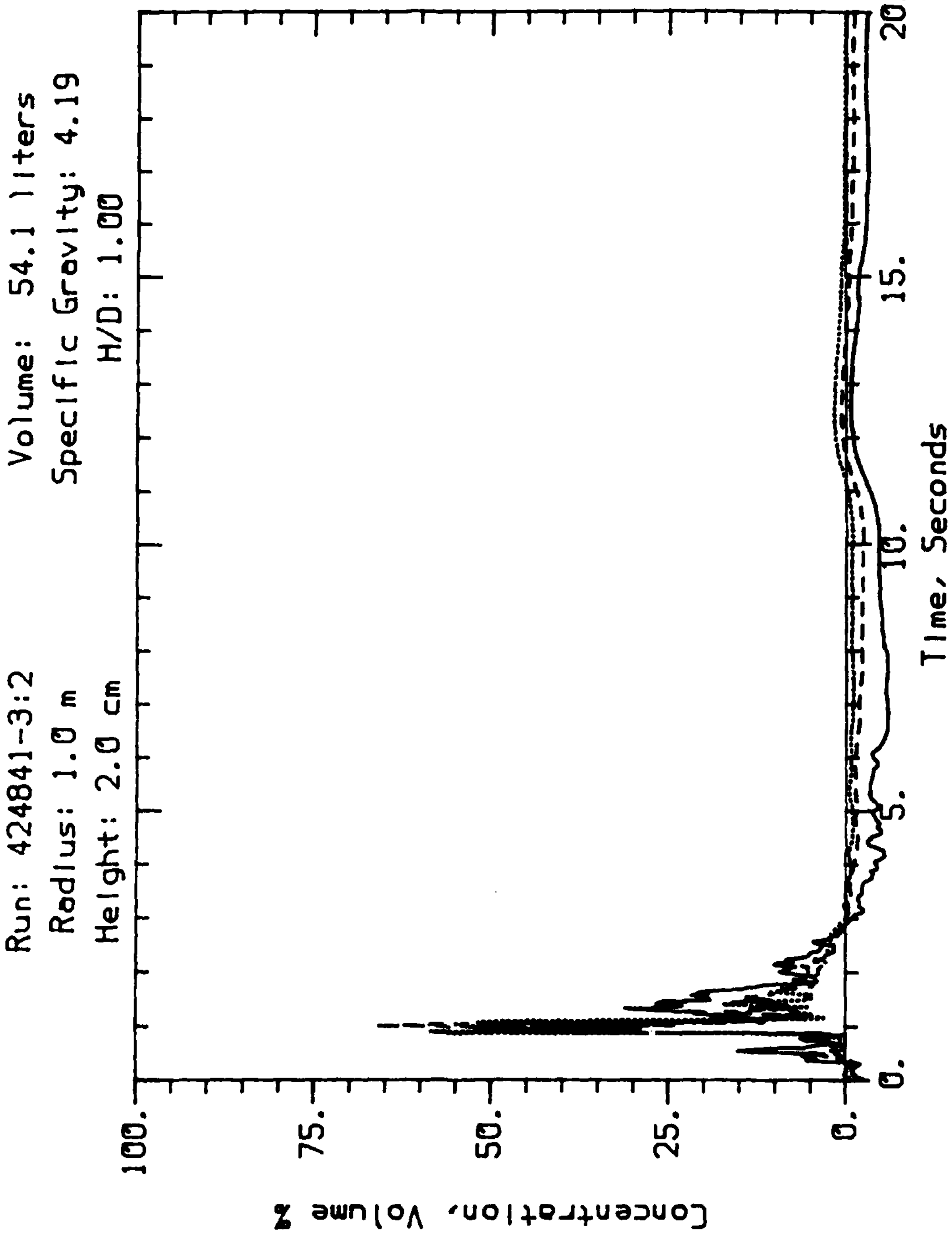

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

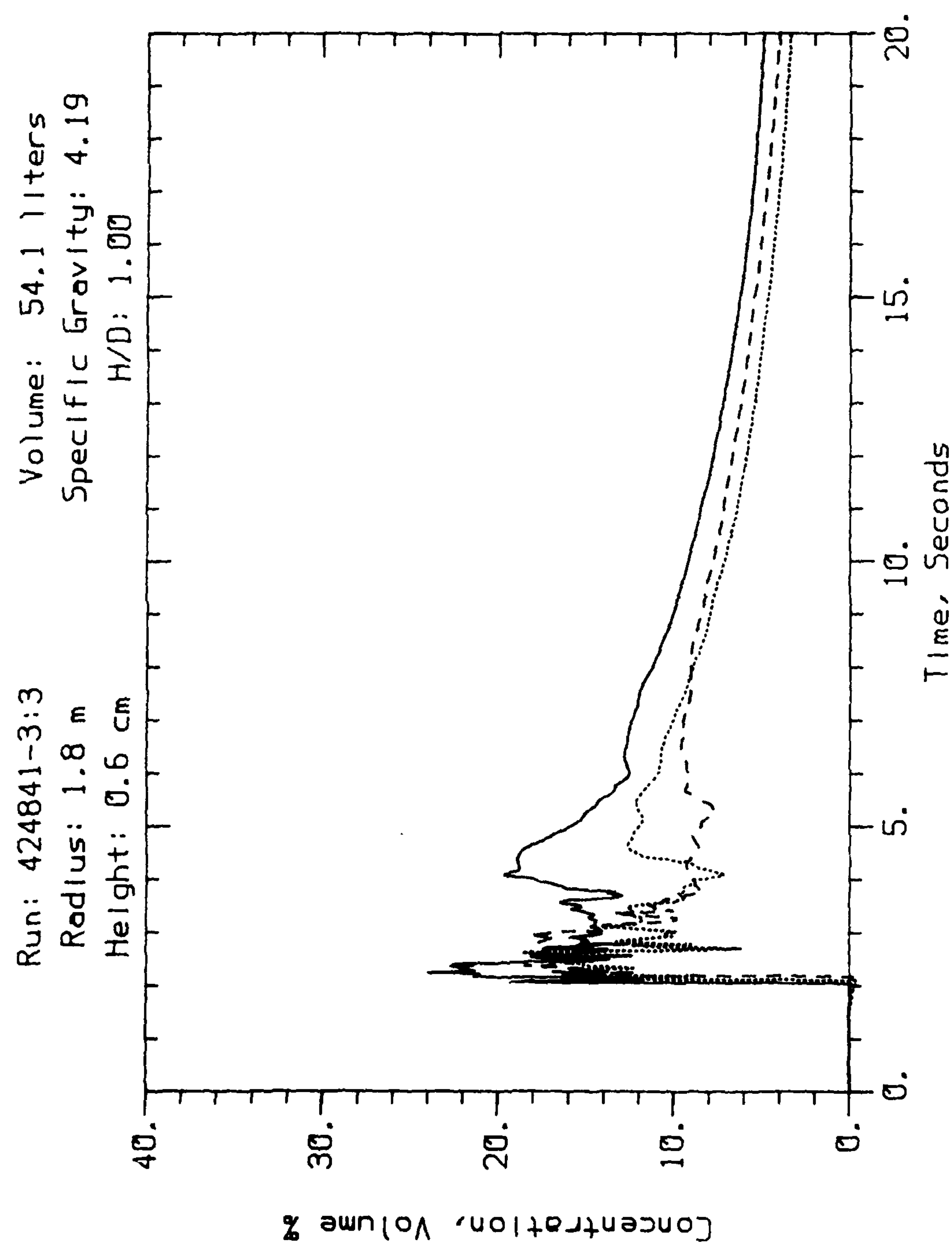

Run: B16831-3:7
Radius: 3.5 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
5.
10.
15.
20.

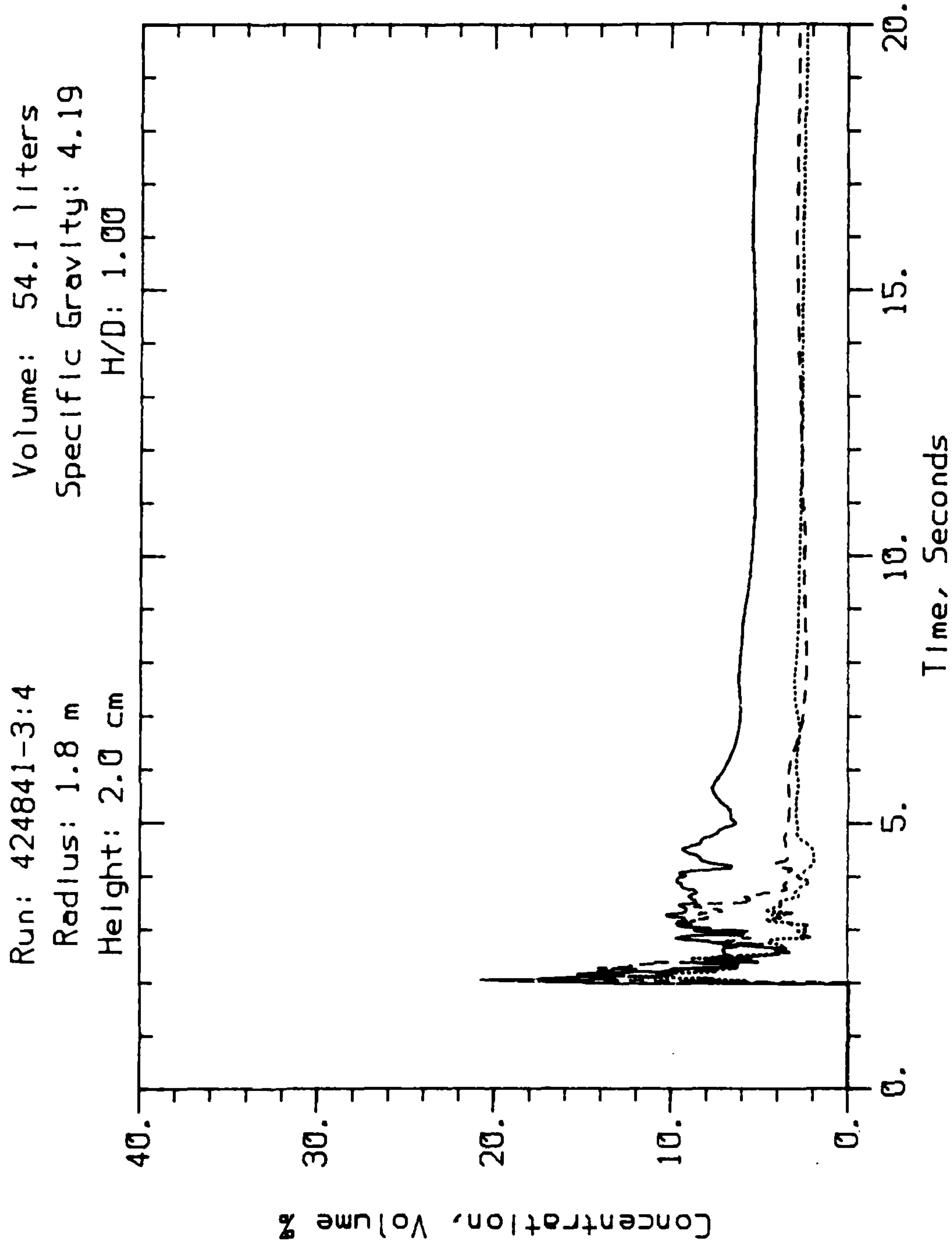

Run: B16831-3:8
Radius: 3.5 m
Height: 11.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Negligible gas concentration
4.0
3.0
2.0
1.0
0.0
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

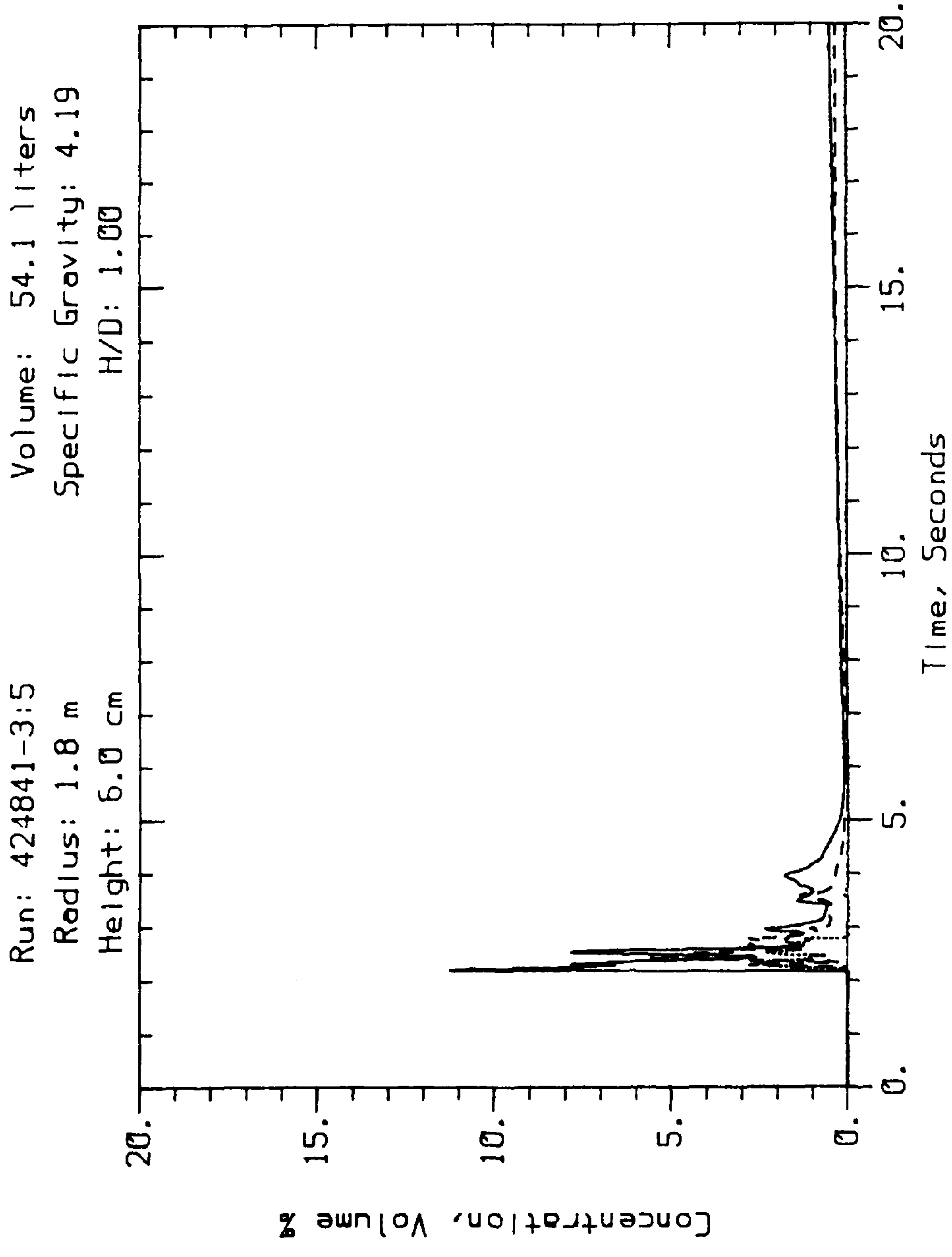


Run: 424841-3:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
100.
75.
50.
25.
0.
5.
10.
15.
20.

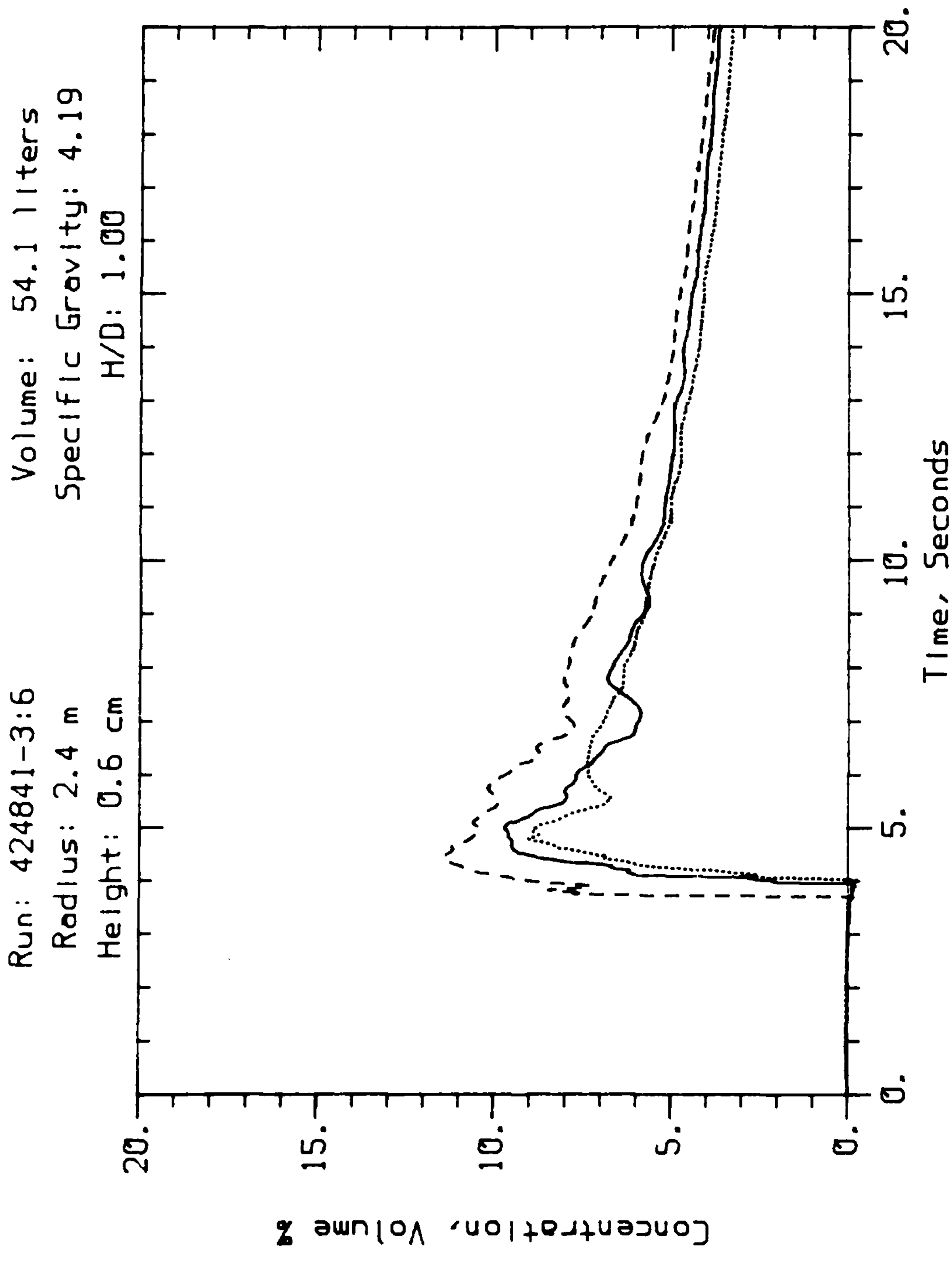

Run: 424841-3:2
Radius: 1.0 m
Height: 2.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
100.
75.
50.
25.
0.
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

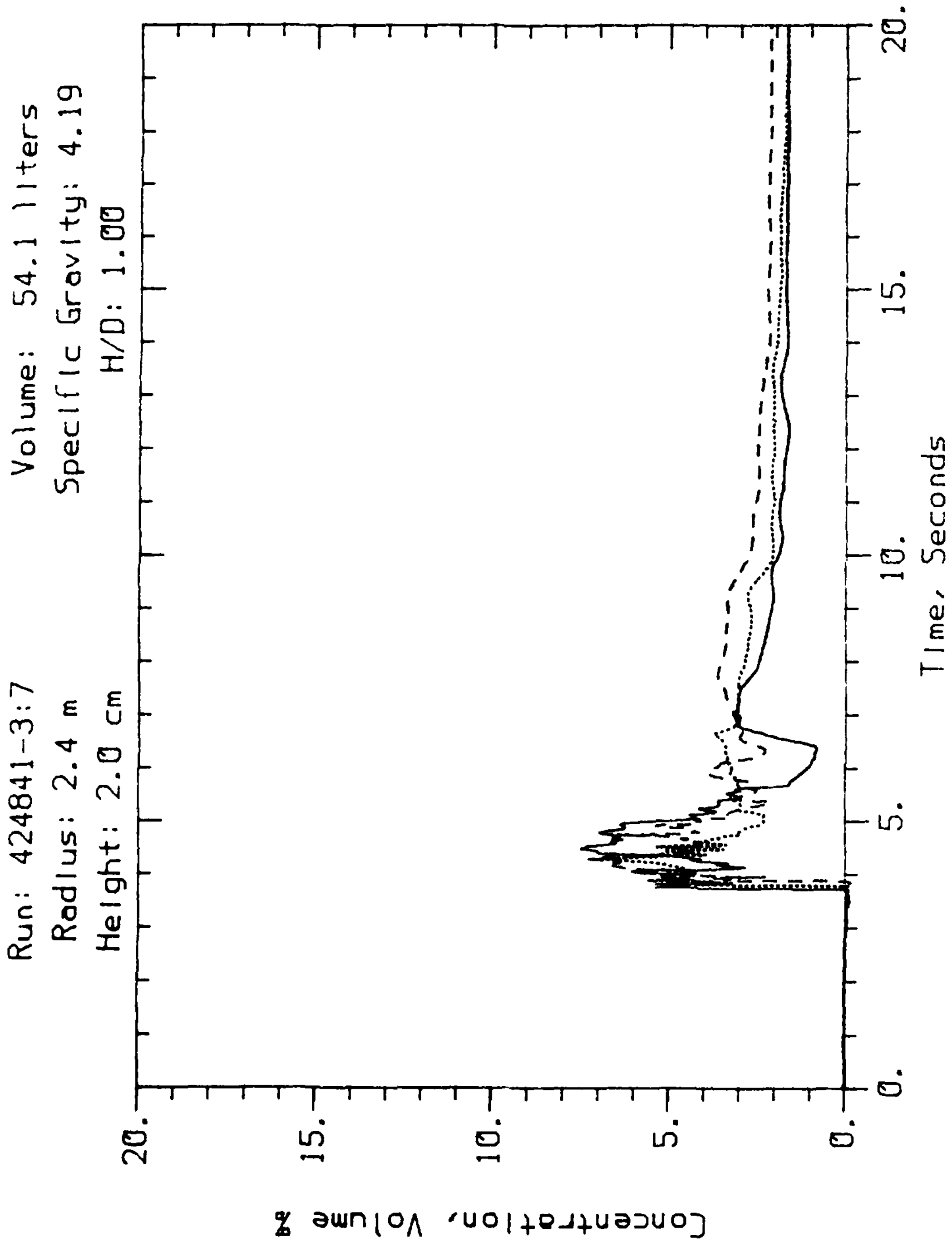

Run: 424841-3:3
Radius: 1.8 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.
10.
20.
30.
40.
Time, Seconds
0.
5.
10.
15.
20.

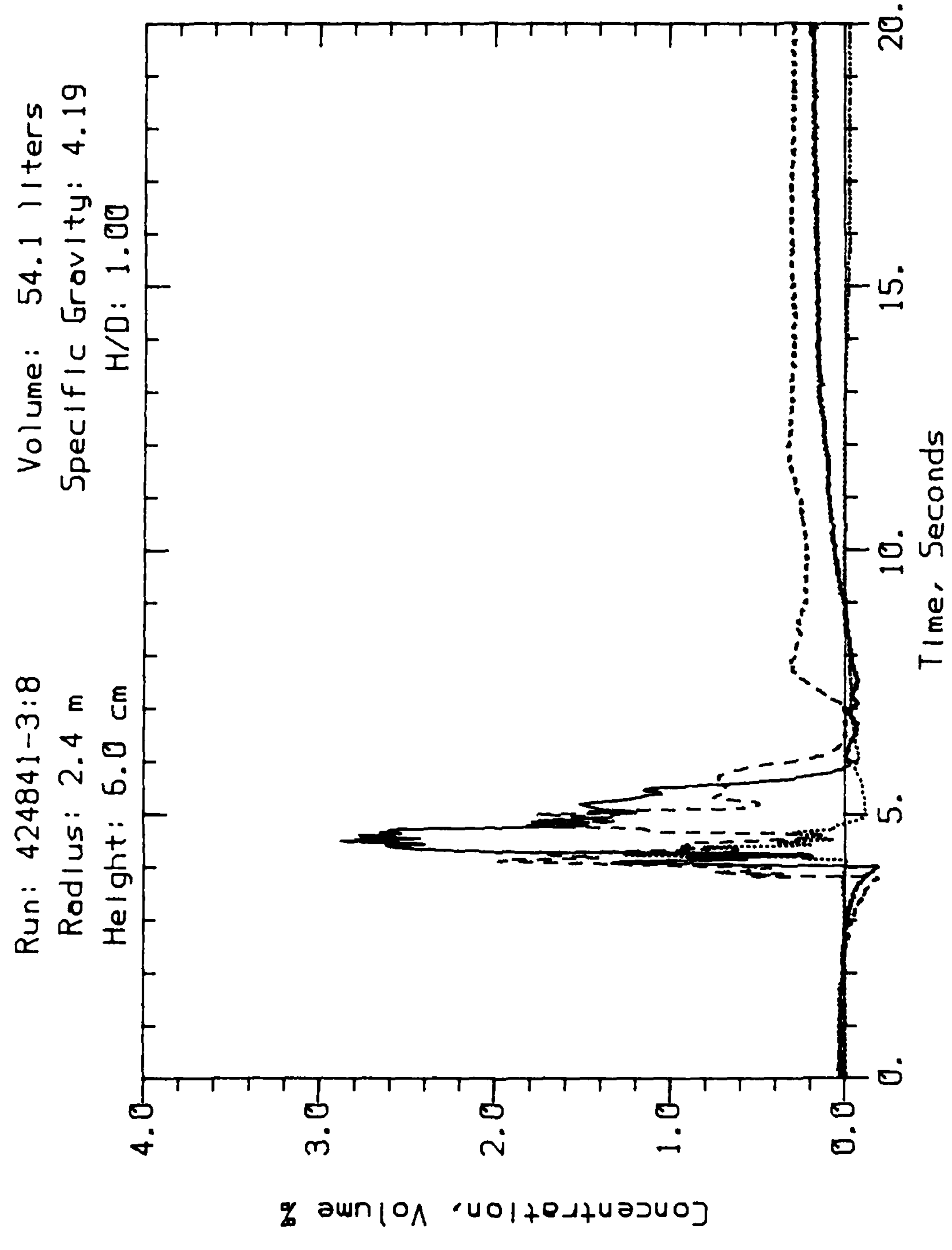

Run: 424841-3:4
Radius: 1.8 m
Height: 2.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.
10.
20.
30.
40.
Time, Seconds
0.
5.
10.
15.
20.

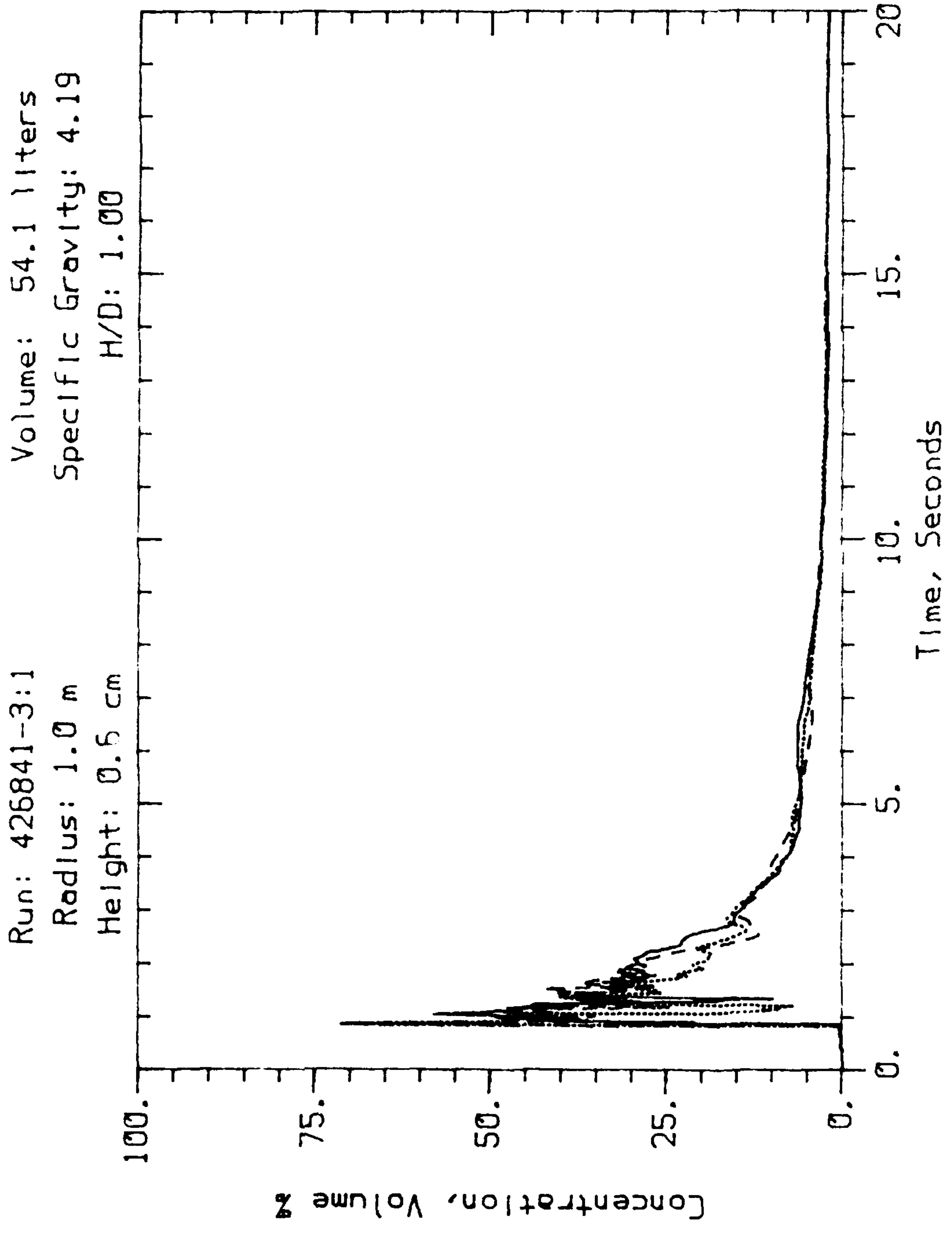


Run: 424841-3:5
Radius: 1.8 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

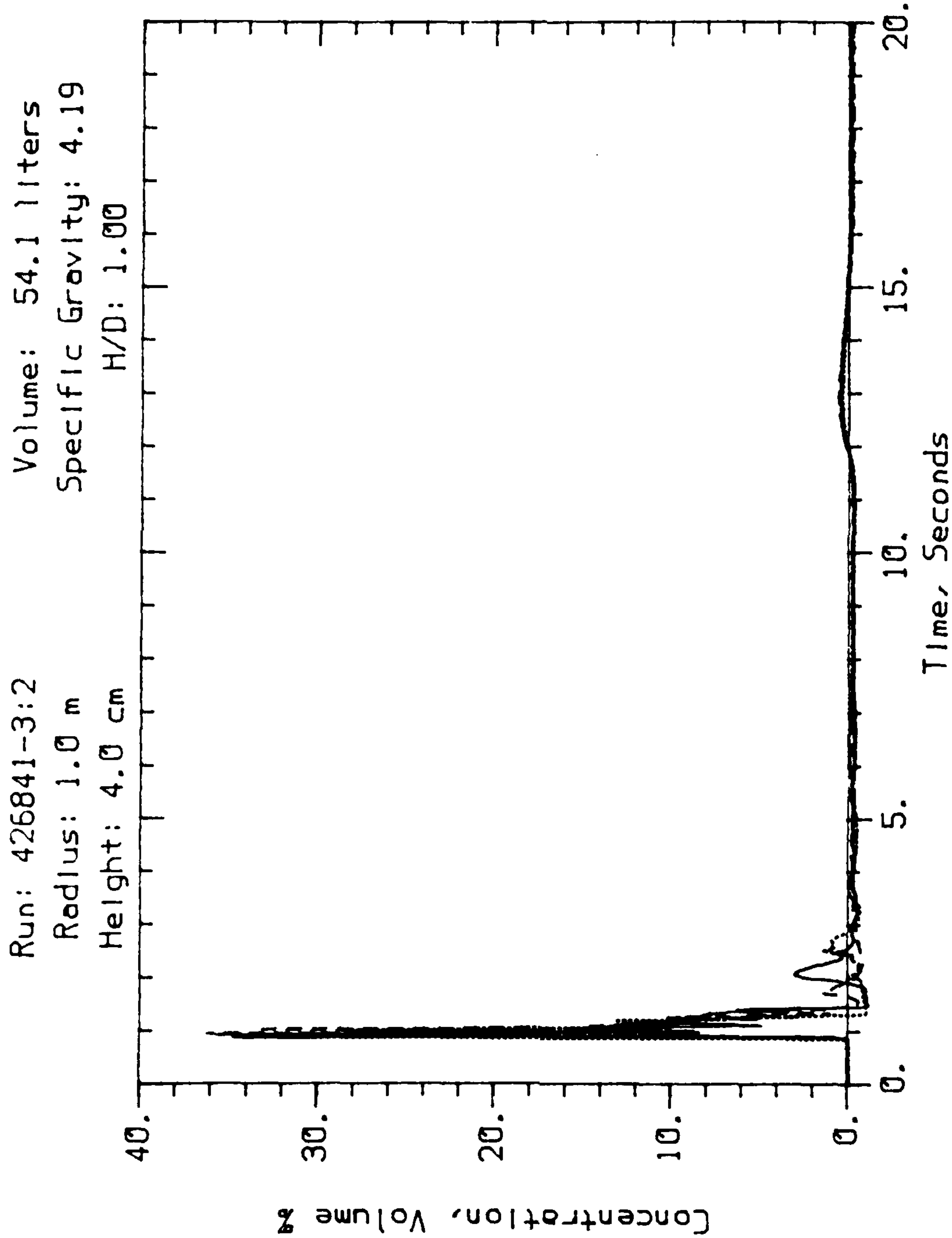

Run: 424841-3:6
Radius: 2.4 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.


Run: 424841-3:7
Radius: 2.4 m
Height: 2.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

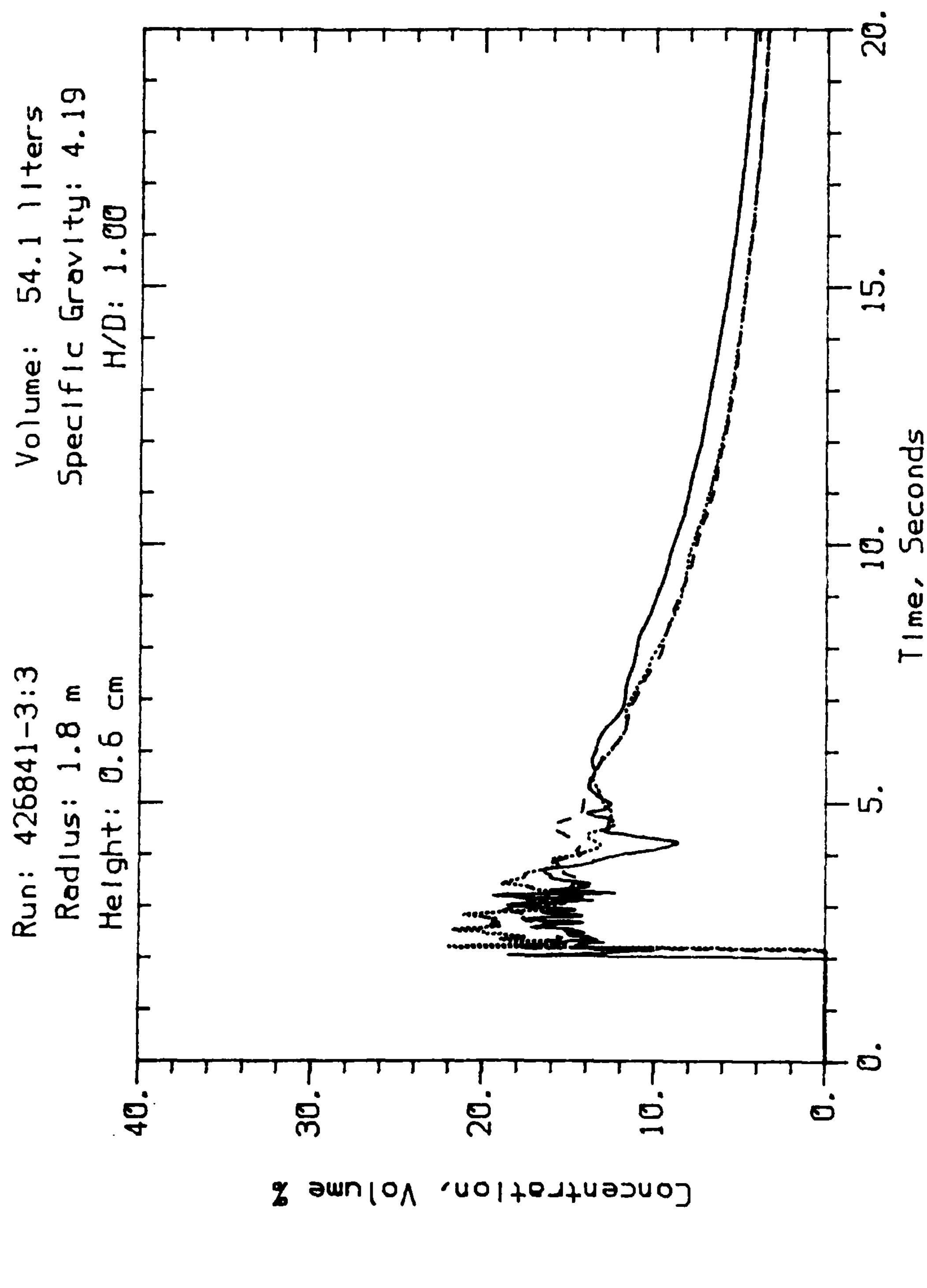

Run: 424841-3:8
Radius: 2.4 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Time, Seconds
Concentration, Volume %
0.
5.
10.
15.
20.
0.0
1.0
2.0
3.0
4.0

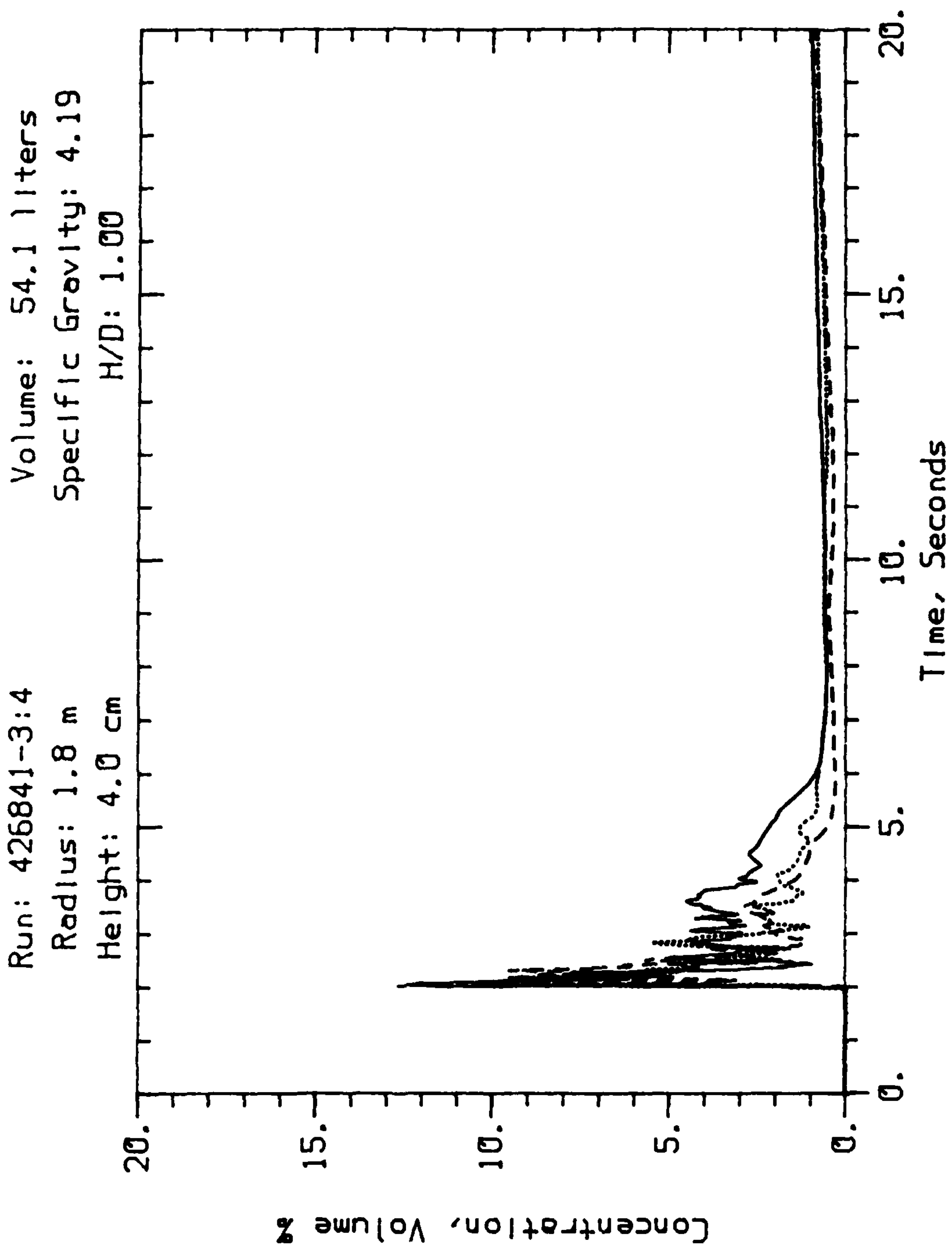


Run: 426841-3:1
Radius: 1.0 m
Height: 0.5 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
100.
75.
50.
25.
0.
0.
5.
10.
15.
20.
Time, Seconds

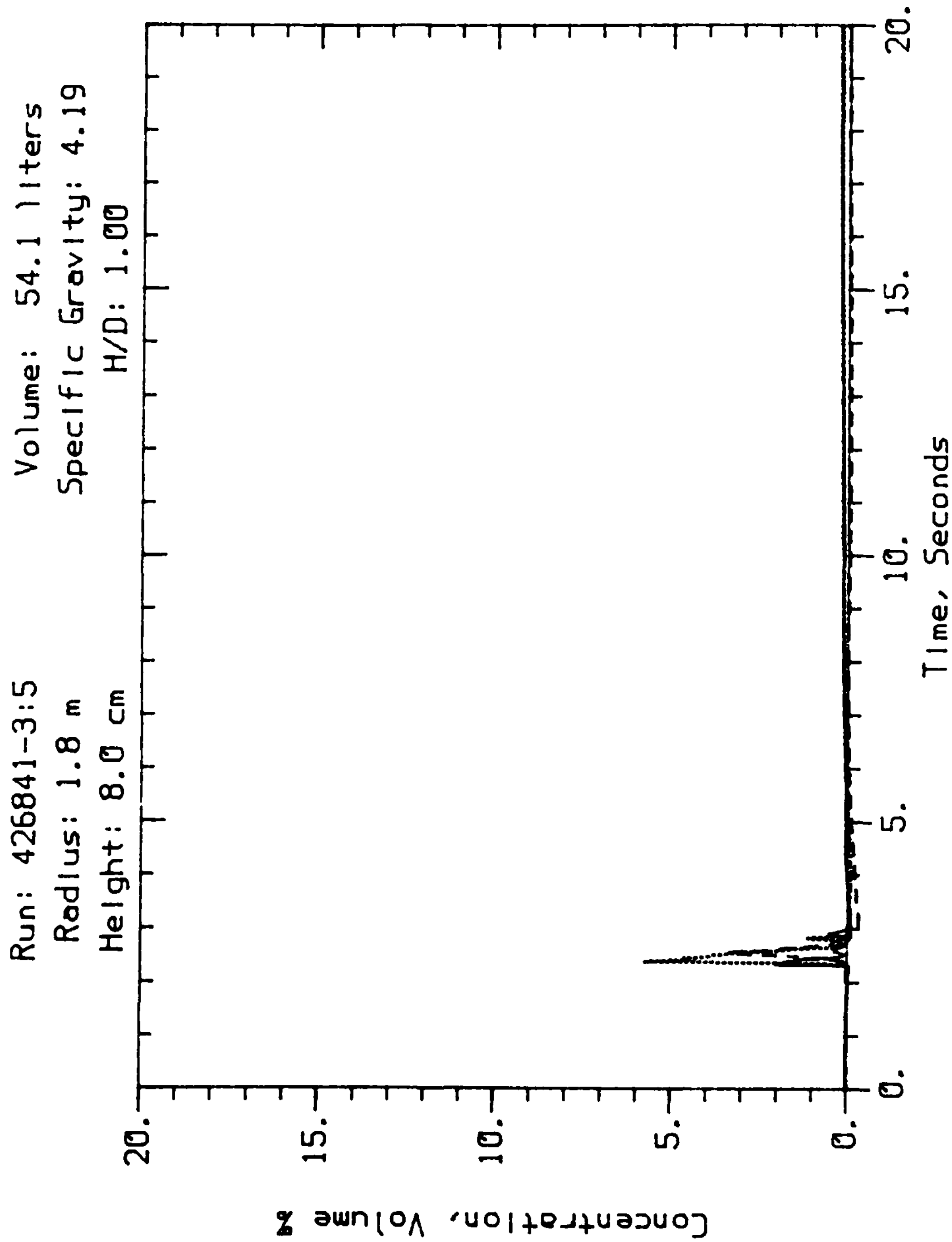


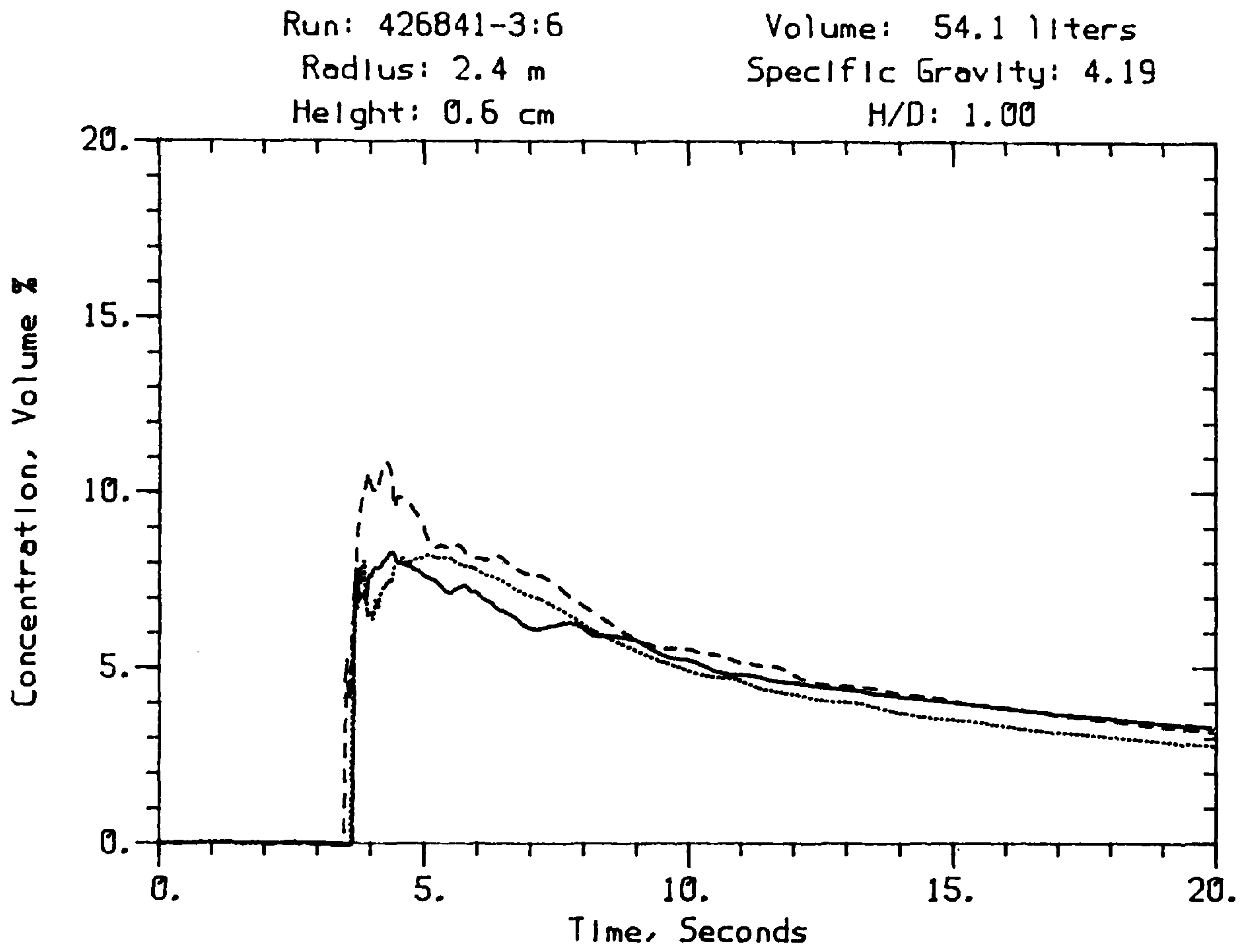
Run: 426841-3:2
Radius: 1.0 m
Height: 4.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
10.
20.
30.
40.
5.
15.

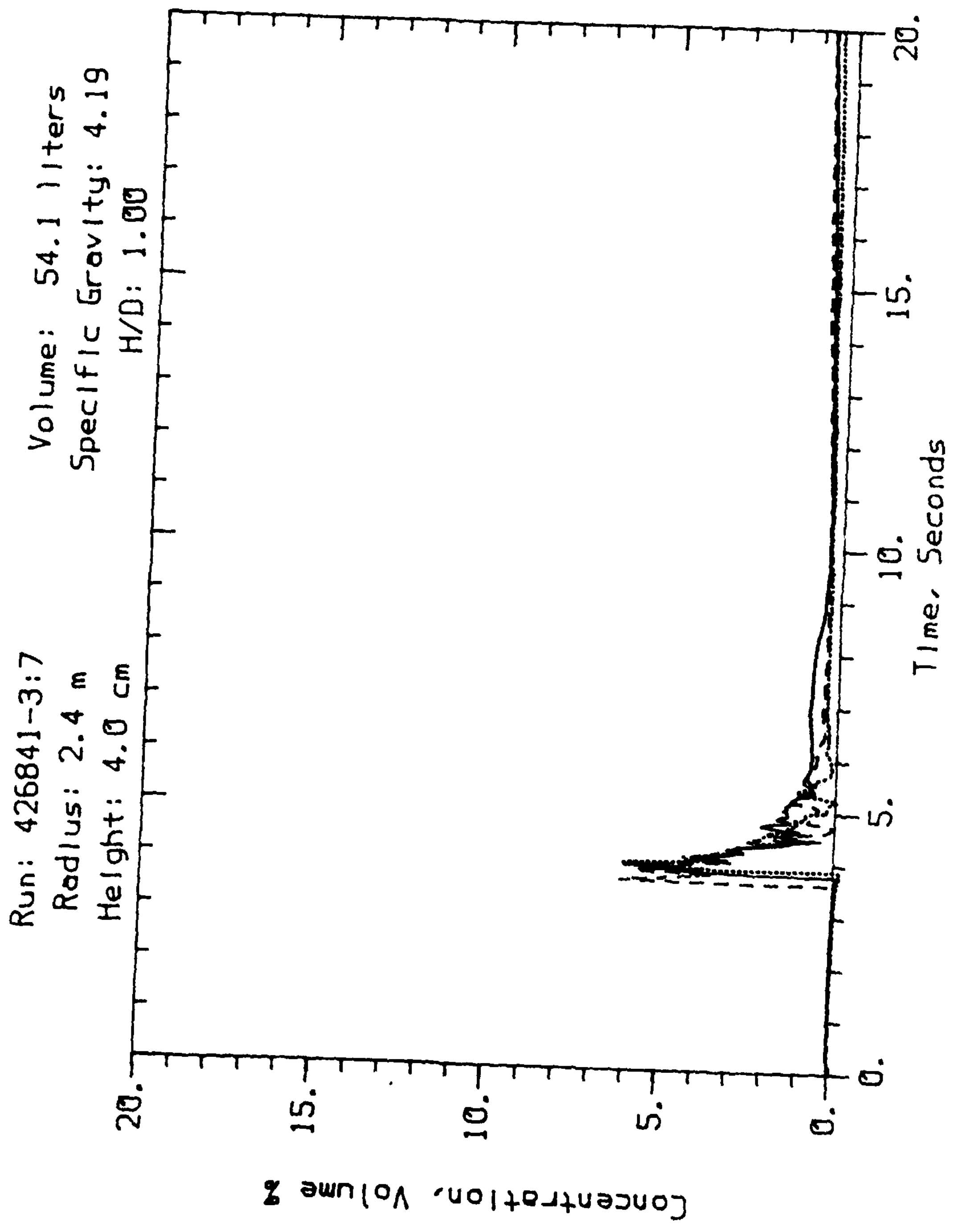

Run: 426841-3:3
Radius: 1.8 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0. 10. 20. 30. 40.
Concentration, Volume %
0. 5. 10. 15. 20.
Time, Seconds

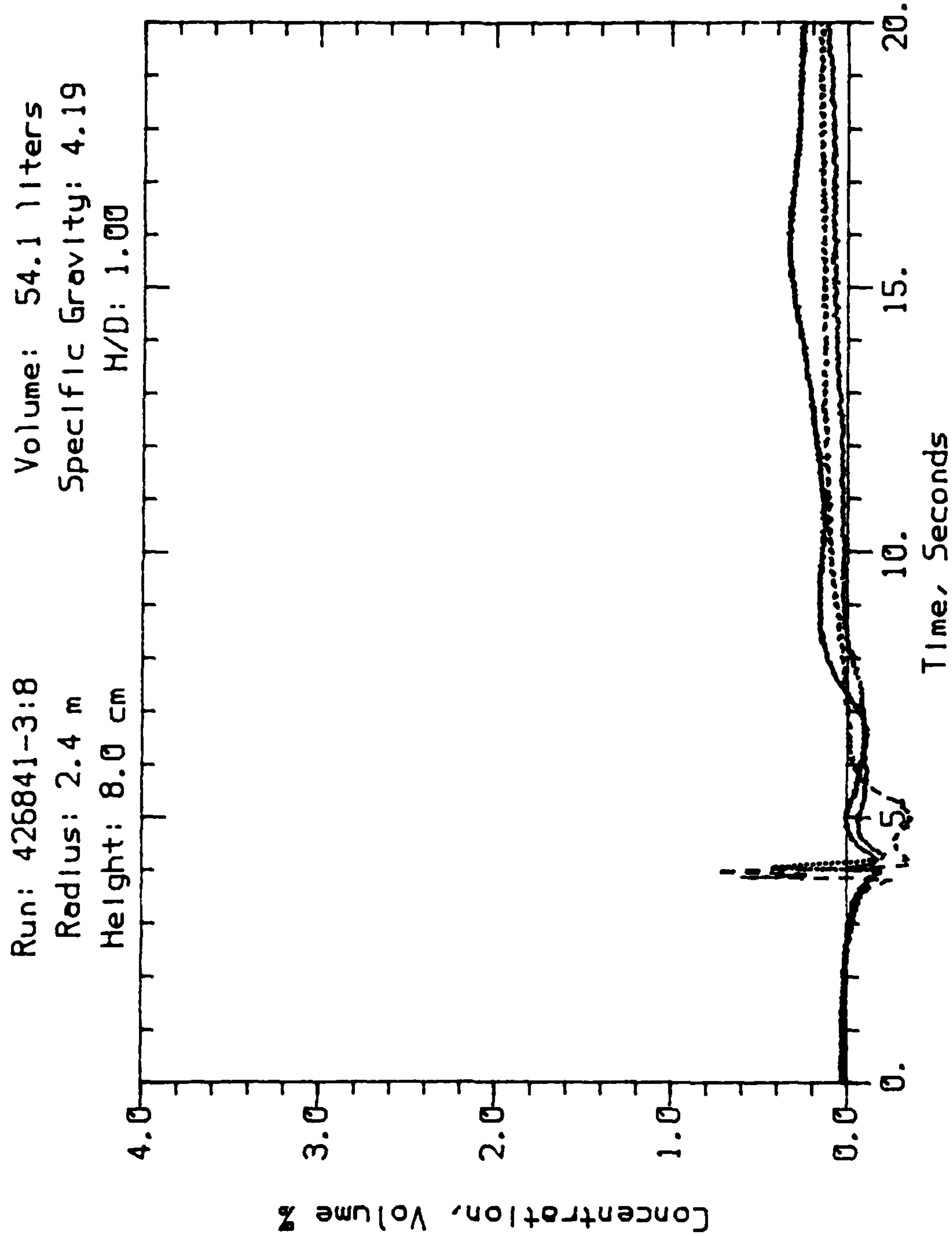


Run: 426841-3:4
Radius: 1.8 m
Height: 4.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.
5.
10.
15.
20.
Concentration, Volume %

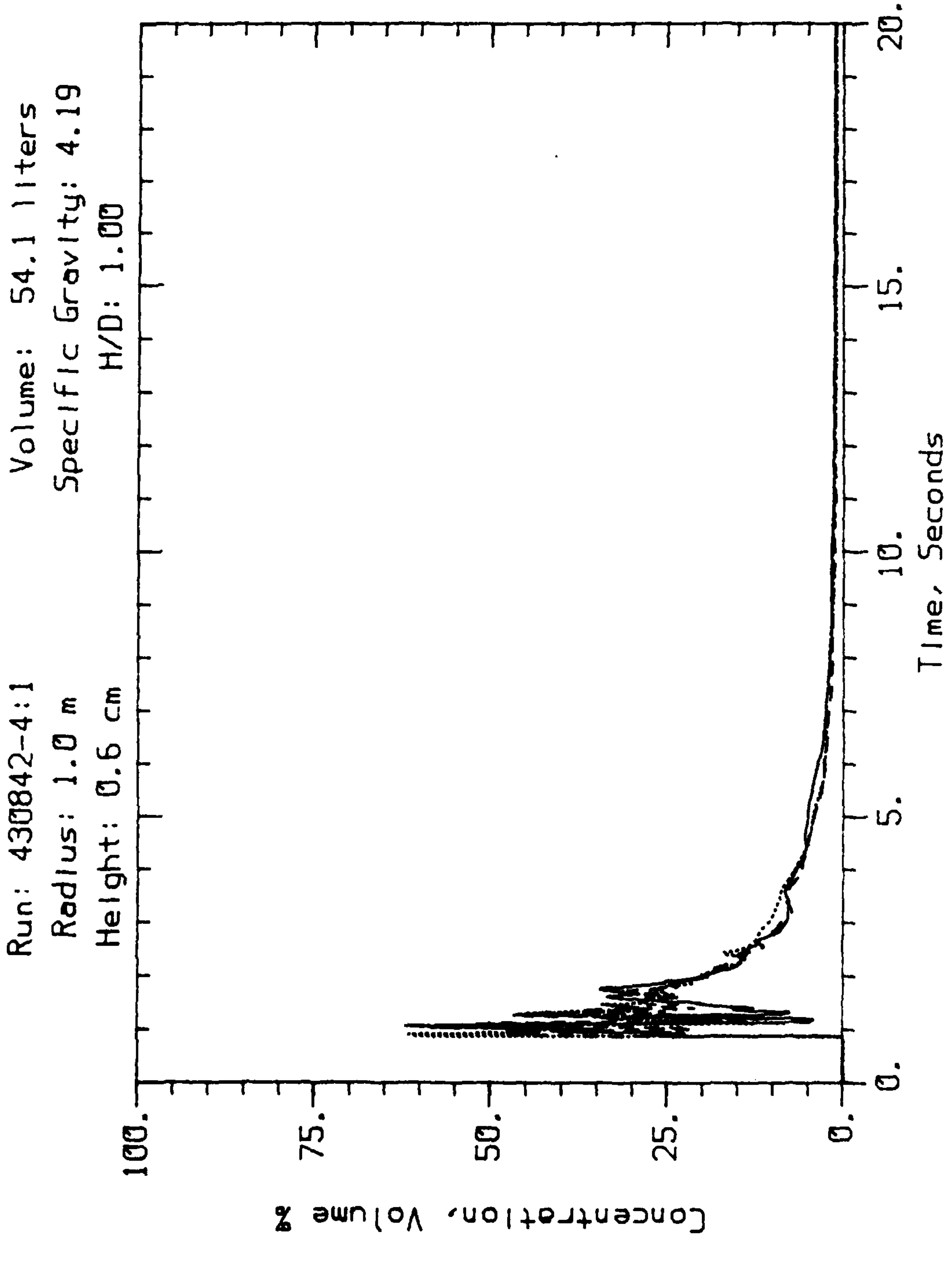

Run: 426841-3:5
Radius: 1.8 m
Height: 8.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
5.
10.
15.
20.

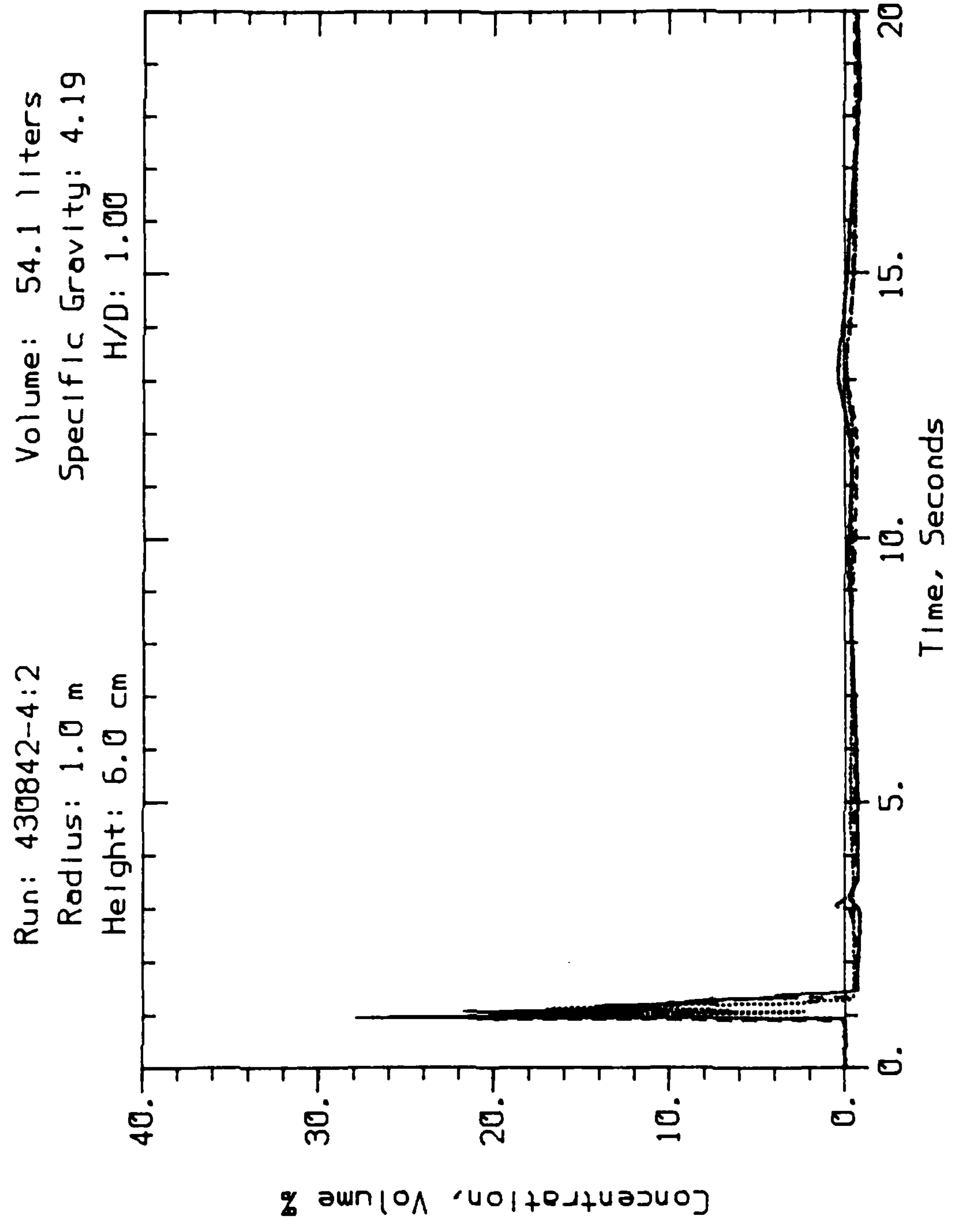

Run: 426841-3:6
Radius: 2.4 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

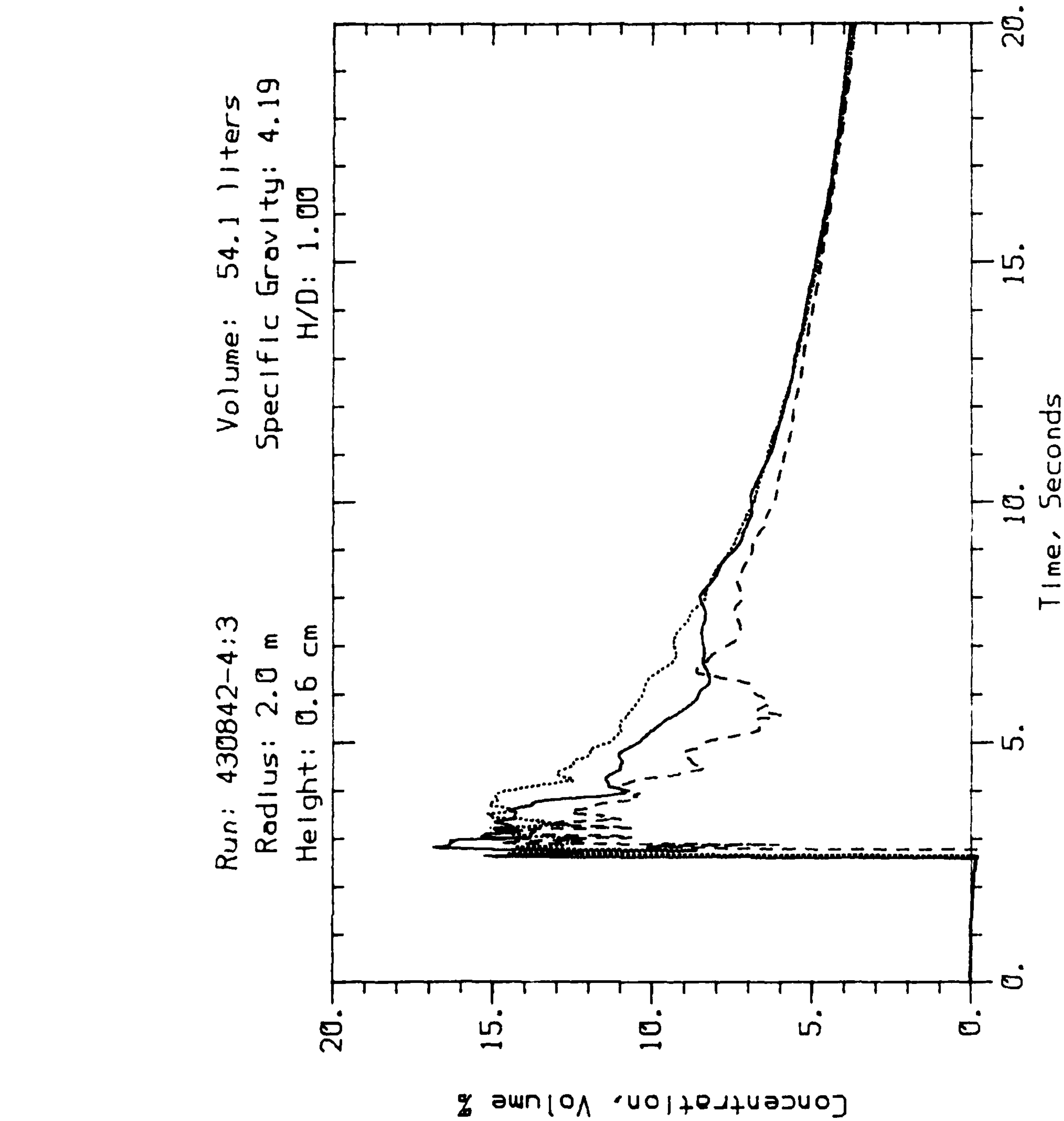

Run: 426841-3:7
Radius: 2.4 m
Height: 4.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Time, Seconds
Concentration, Volume %
0.
5.
10.
15.
20.



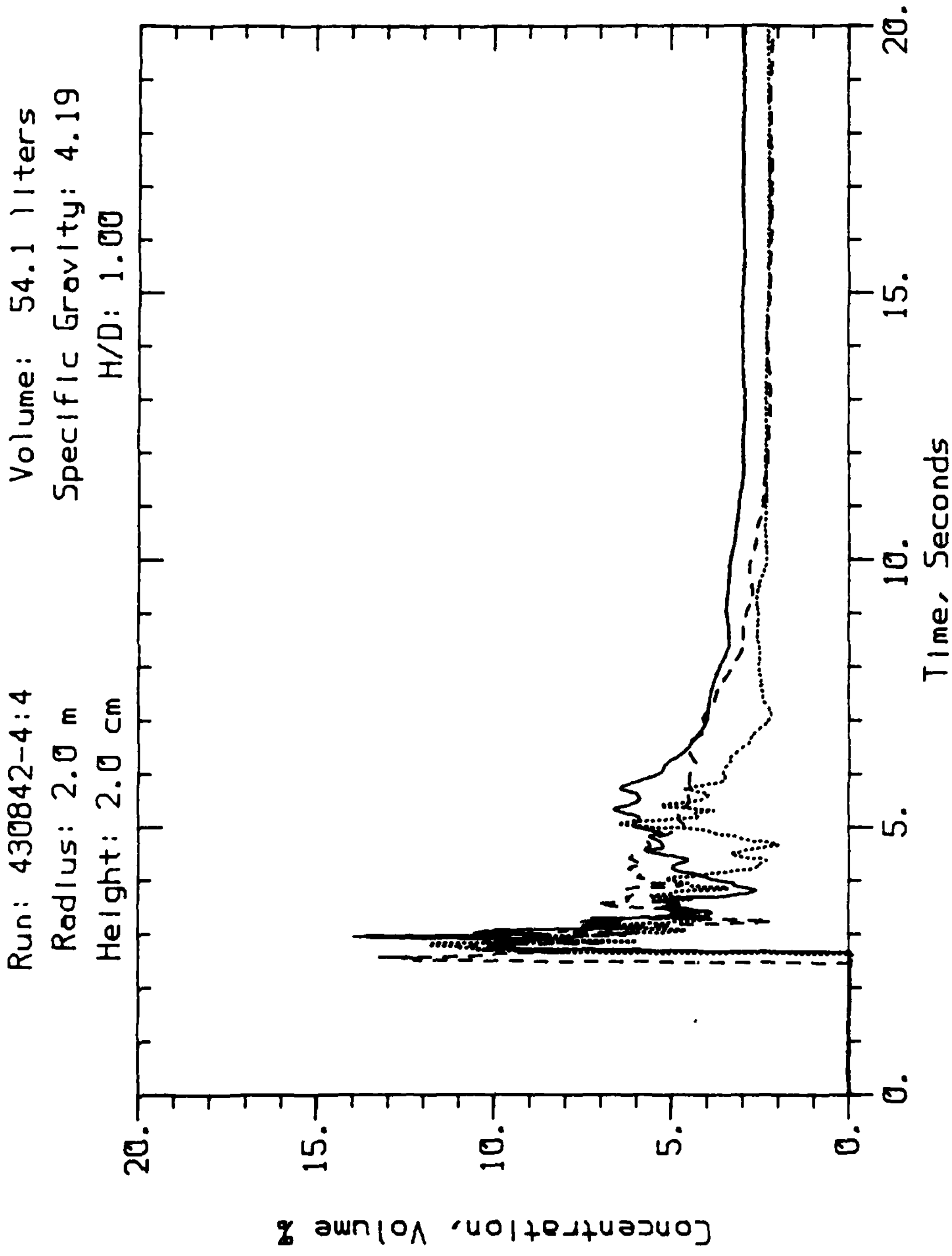
Run: 426841-3:8
Radius: 2.4 m
Height: 8.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
10.
15.
20.
Time, Seconds
0.0
1.0
2.0
3.0
4.0
Concentration, Volume %
5

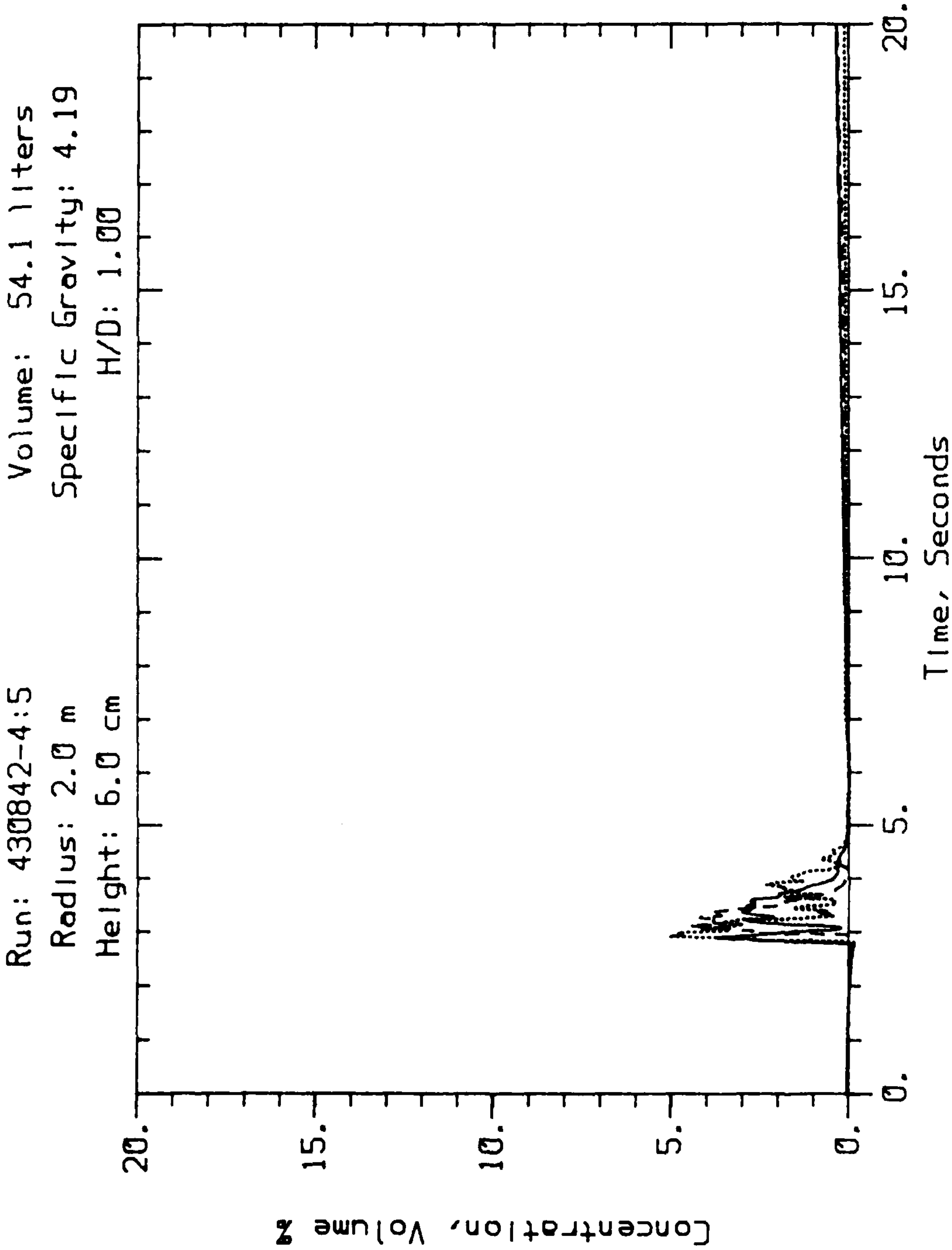

Run: 430842-4:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
100.
75.
50.
25.
0.
0.
5.
10.
15.
20.
Time, Seconds


Run: 430842-4:2
Radius: 1.0 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.
10.
20.
30.
40.
Concentration, Volume %

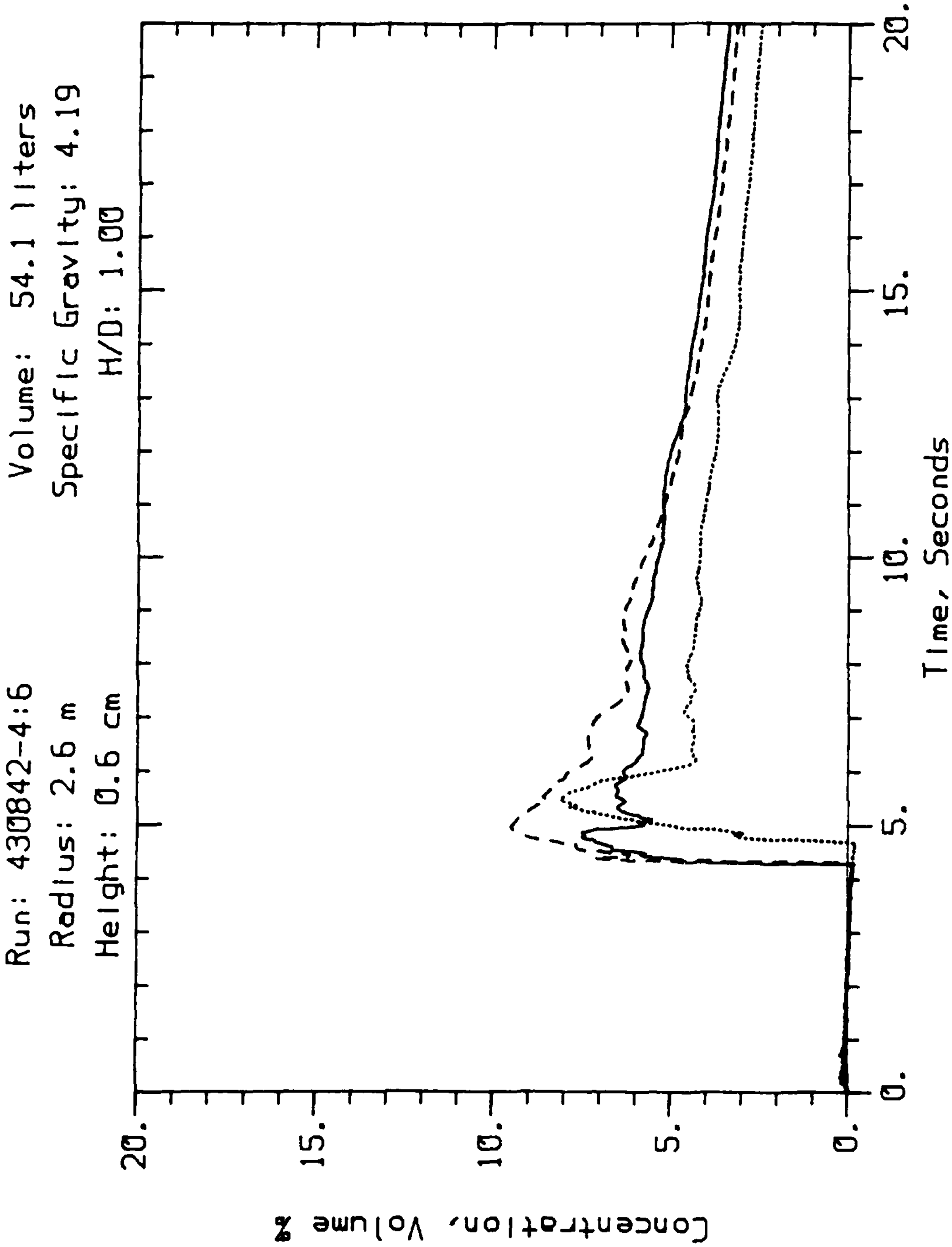


Run: 430842-4:3
Radius: 2.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

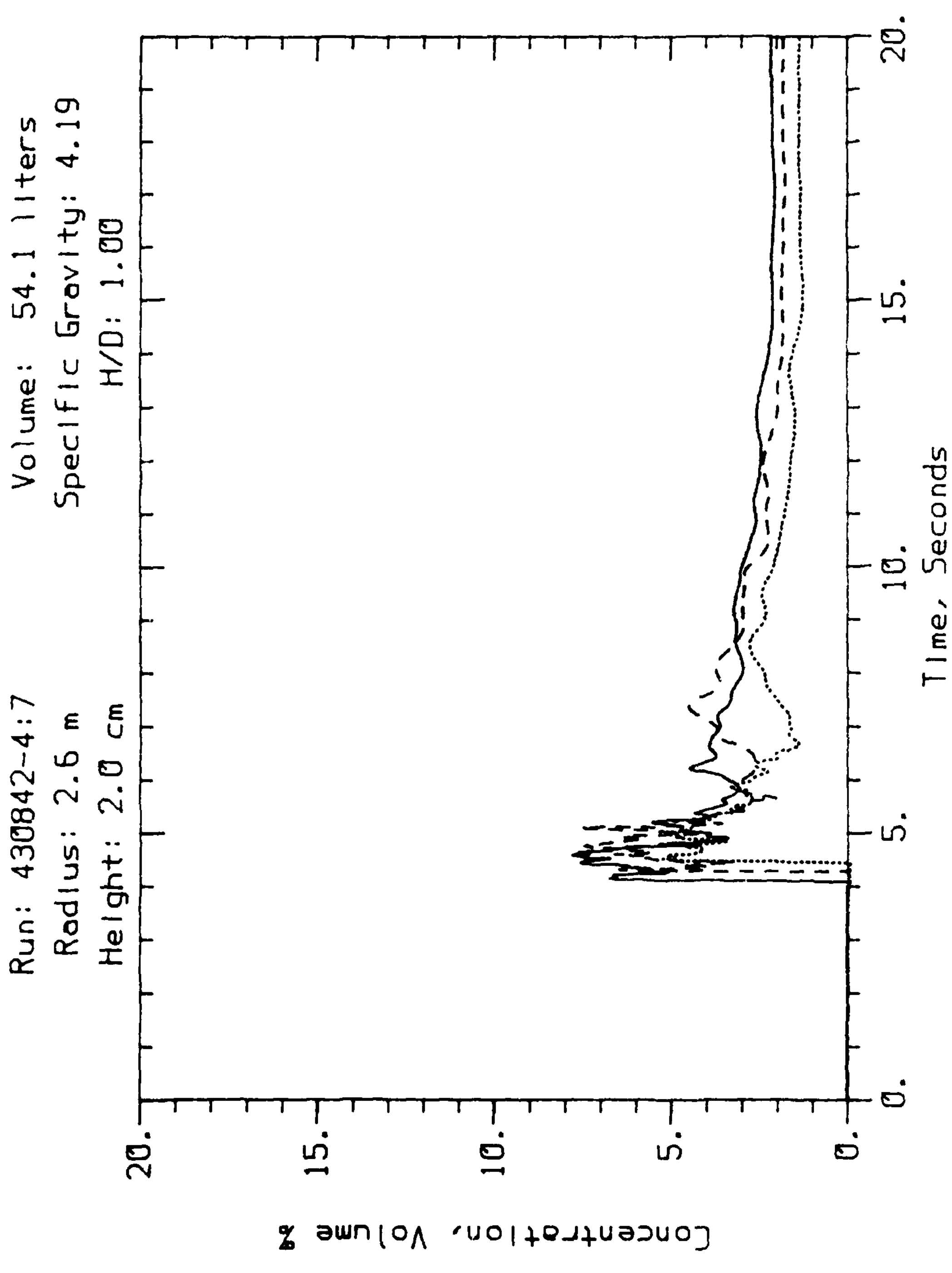

Run: 430842-4:4
Radius: 2.0 m
Height: 2.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

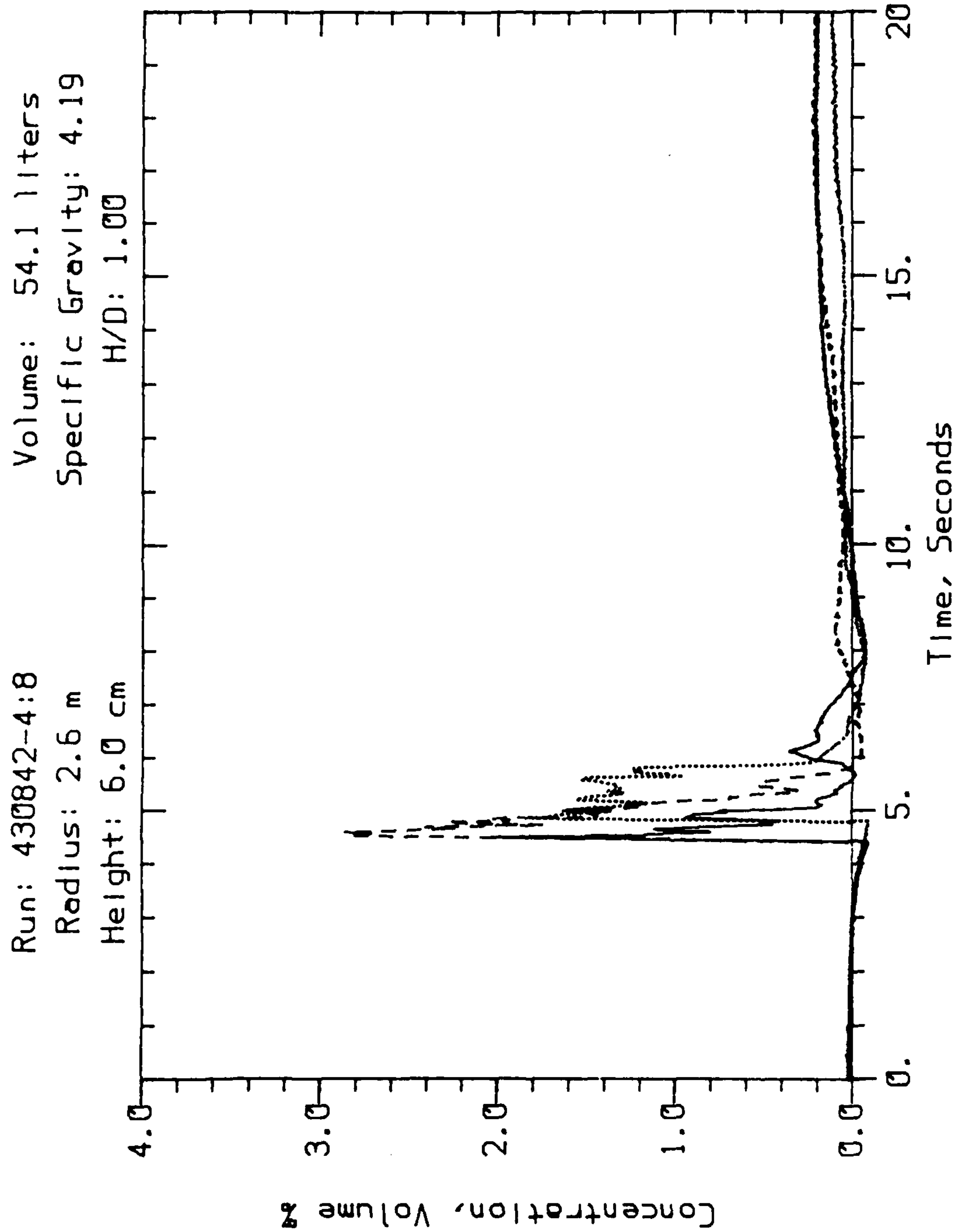


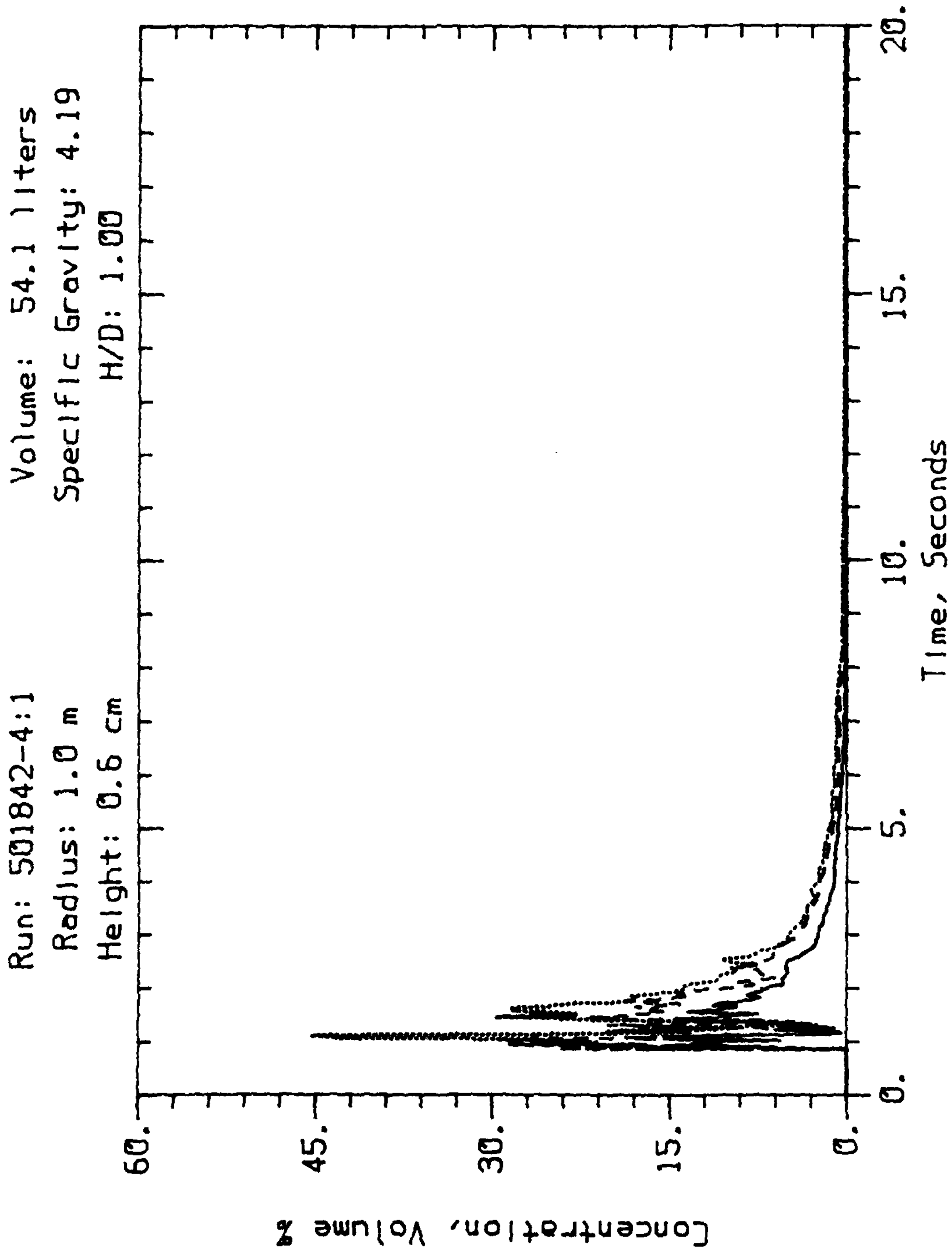
Run: 430842-4:5
Radius: 2.0 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.



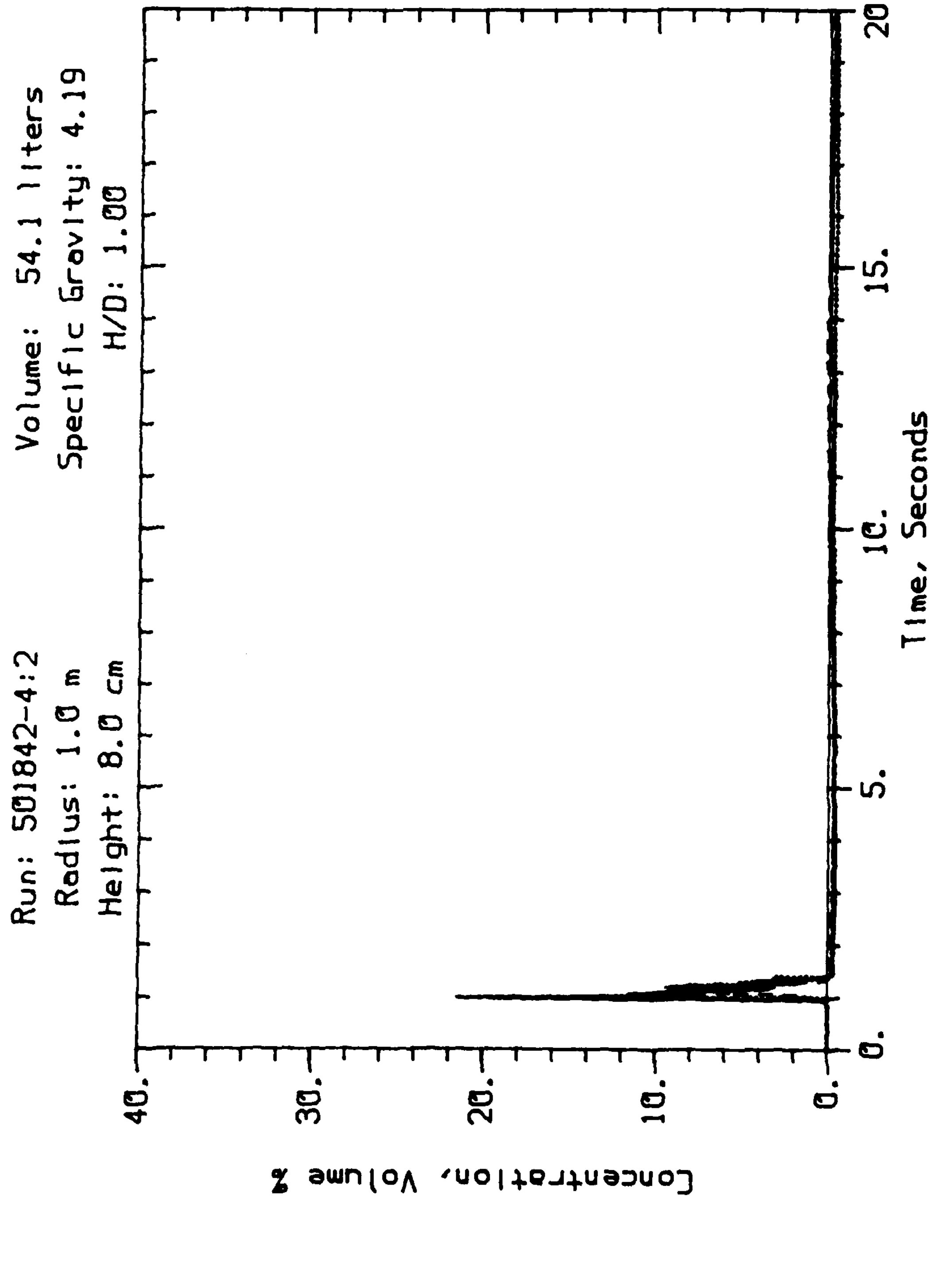
Run: 430842-4:6
Radius: 2.6 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
Concentration, Volume %

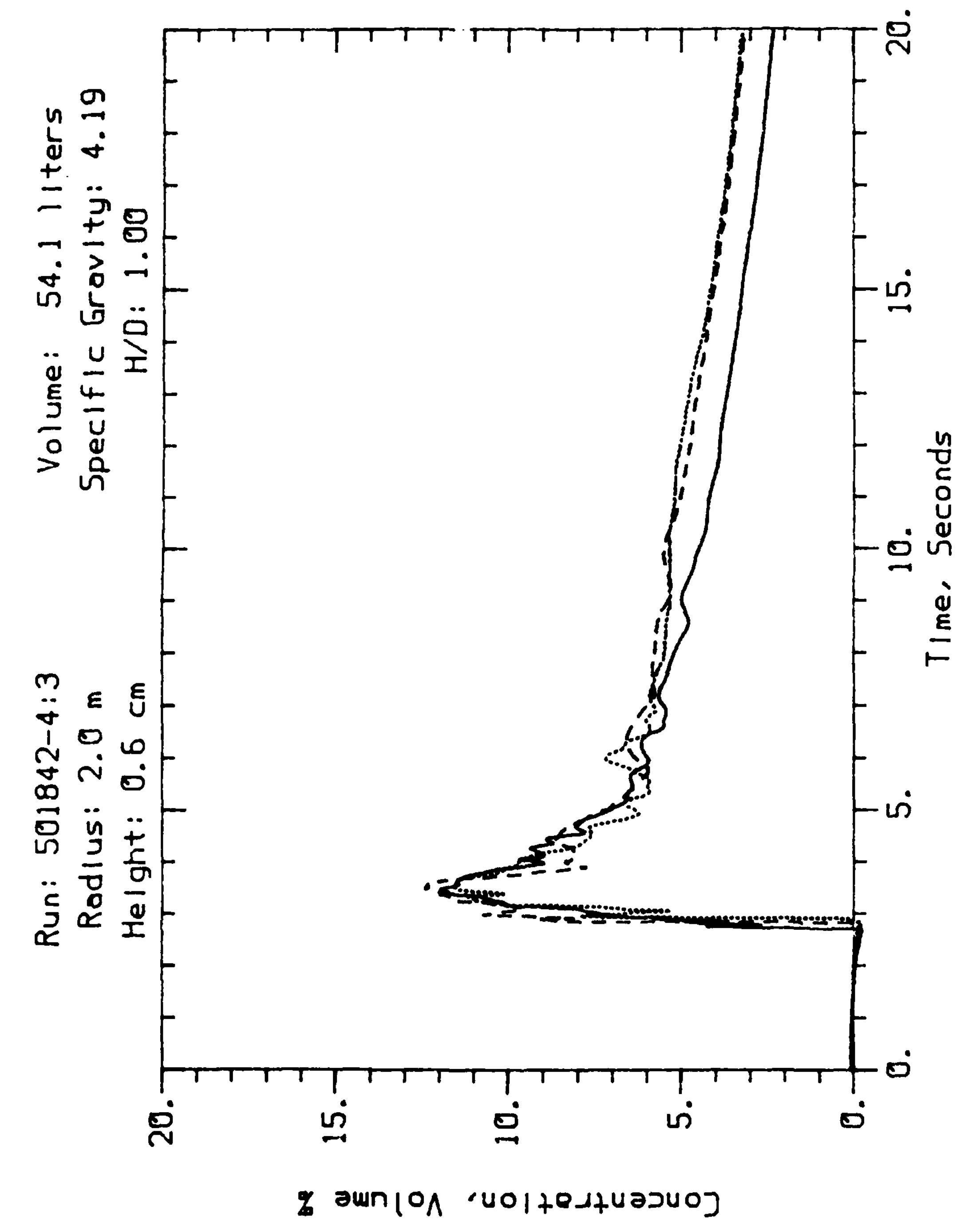

Run: 430842-4:7
Radius: 2.6 m
Height: 2.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
5.
10.
15.
20.


Run: 430842-4:8
Radius: 2.6 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.0
1.0
2.0
3.0
4.0
Concentration, Volume %

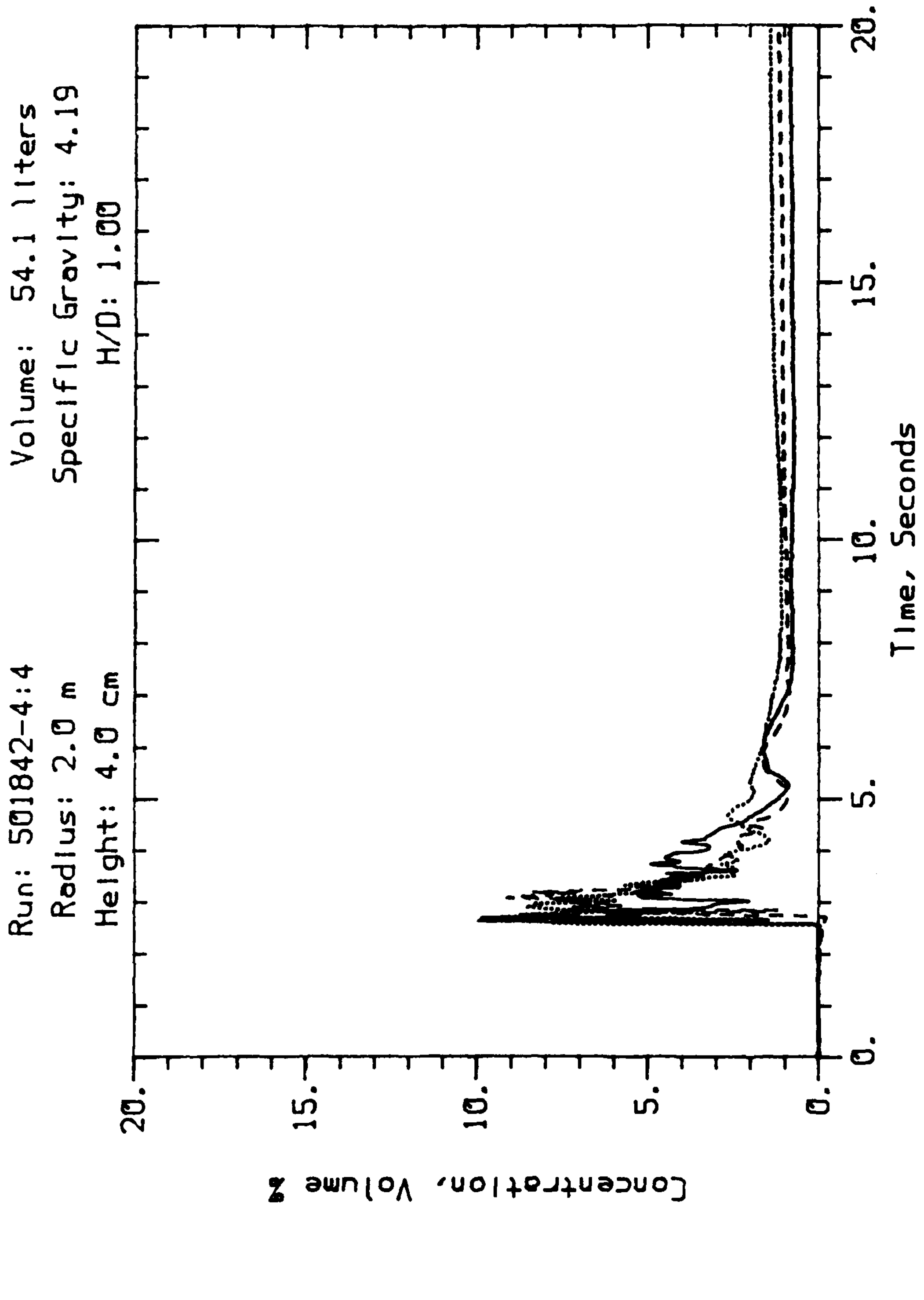


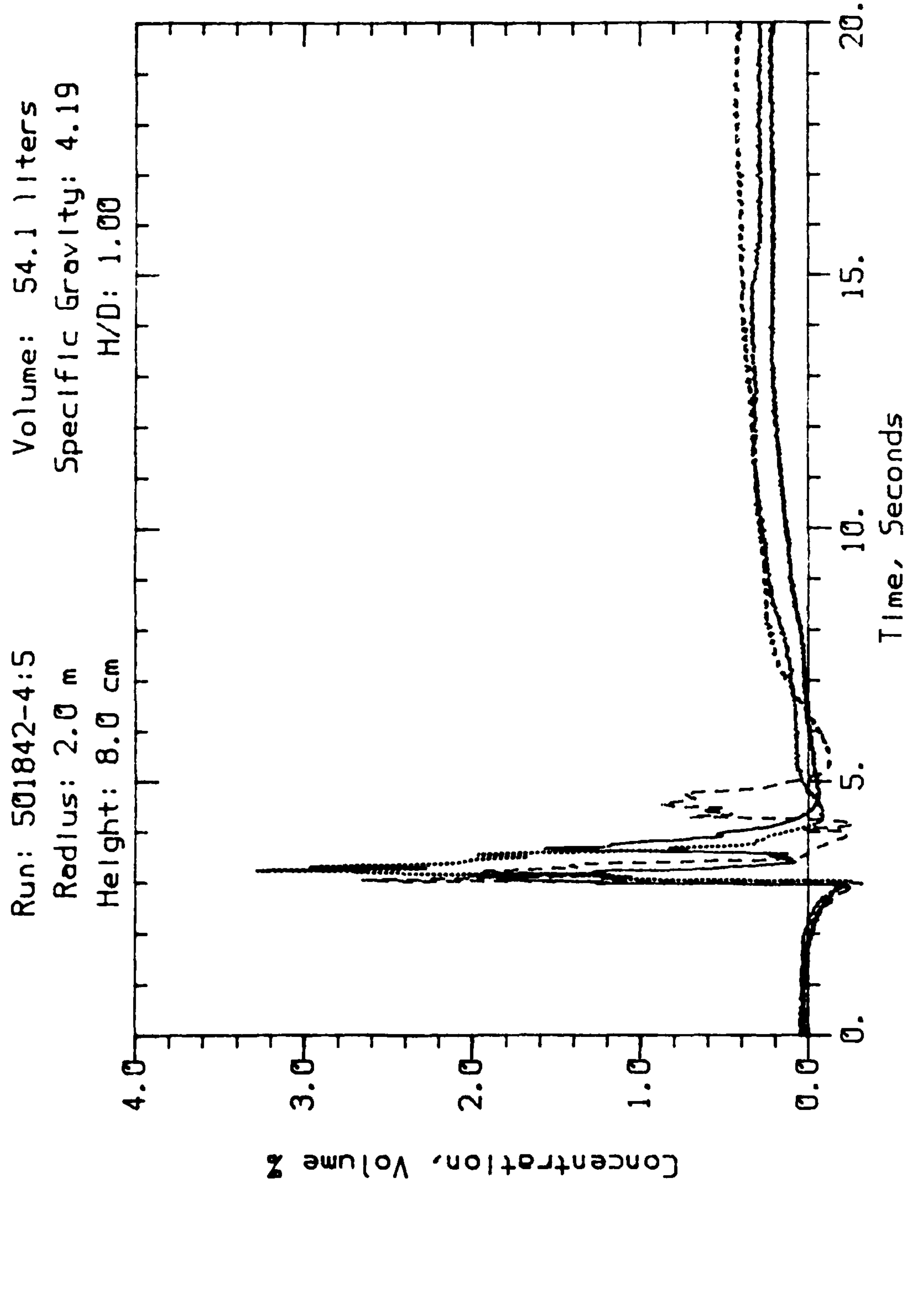
Run: 501842-4:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
60.
45.
30.
15.
0.
Time, Seconds
0.
5.
10.
15.
20.

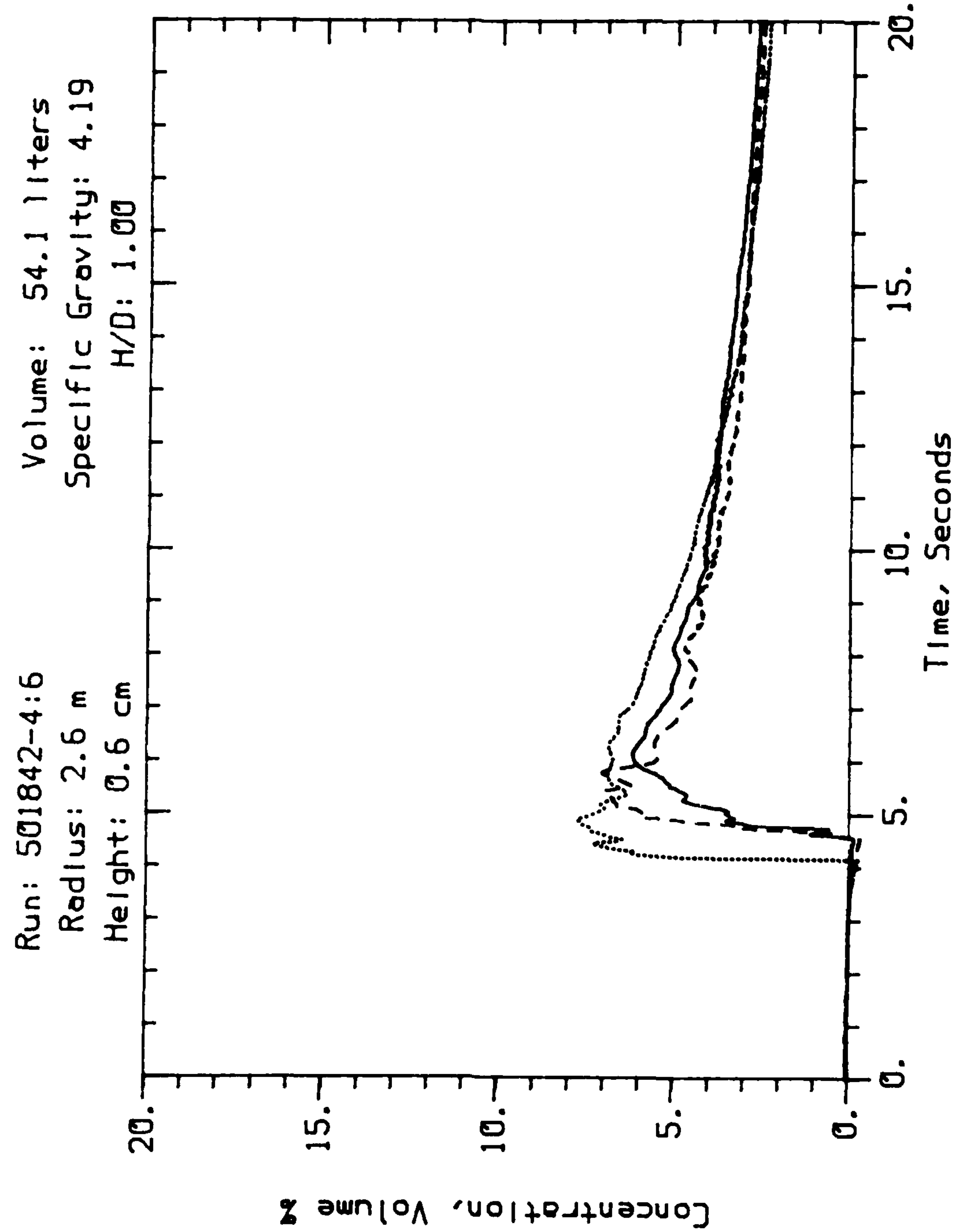

Run: 501842-4:2
Radius: 1.0 m
Height: 8.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Time, Seconds
0.
5.
10.
15.
20.
Concentration, Volume %
0.
10.
20.
30.
40.

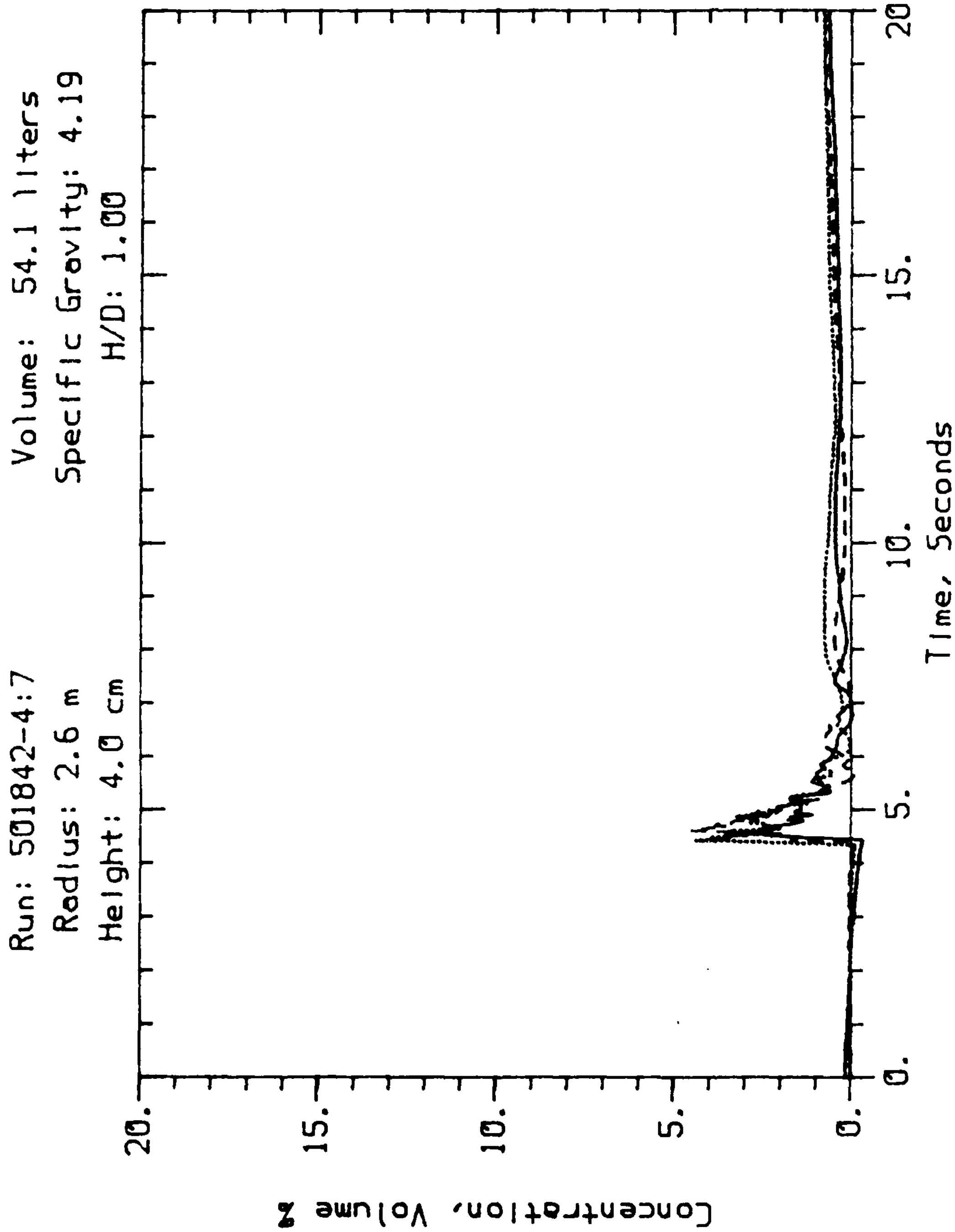


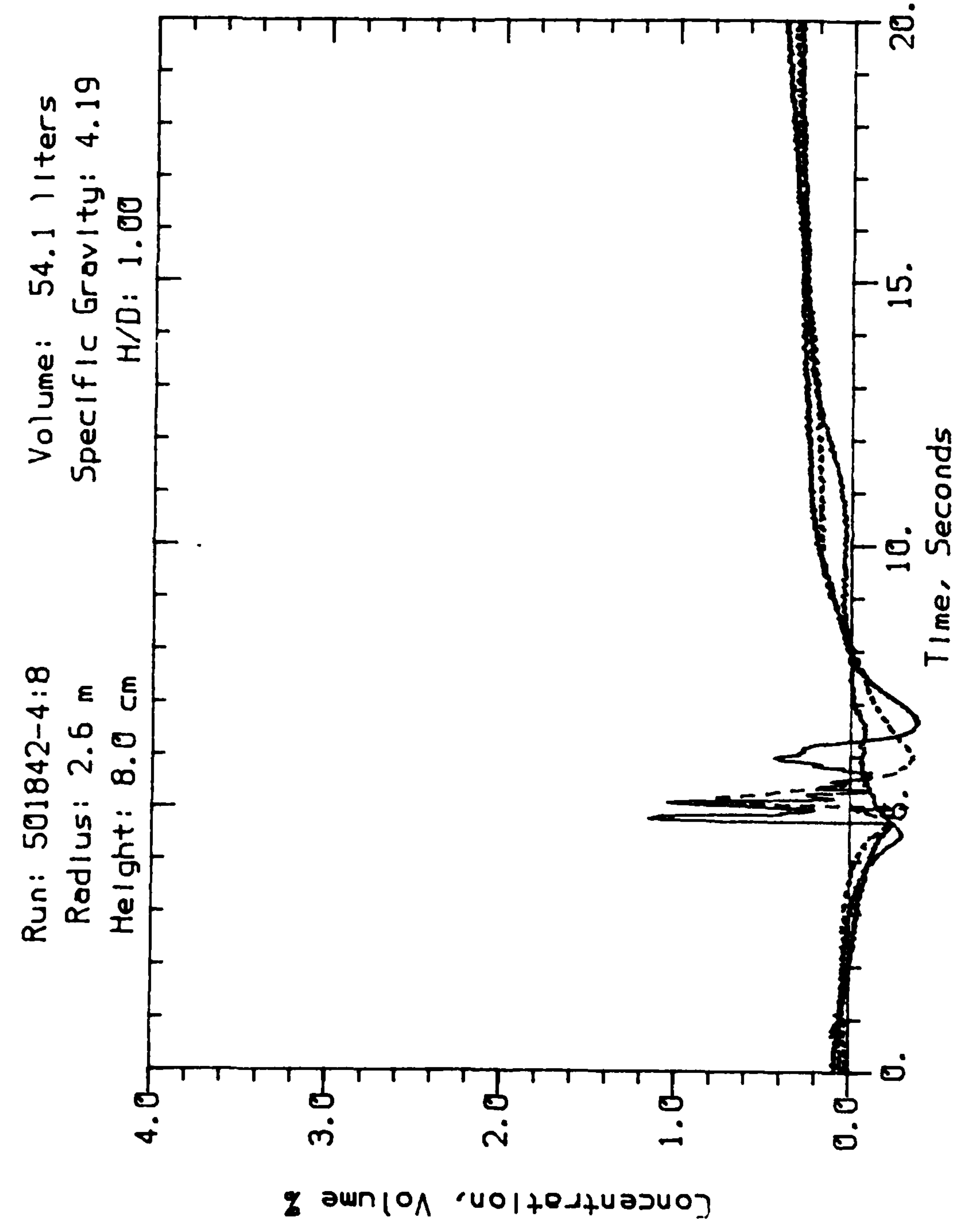
Run: 501842-4:3
Radius: 2.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
5.
10.
15.
20.

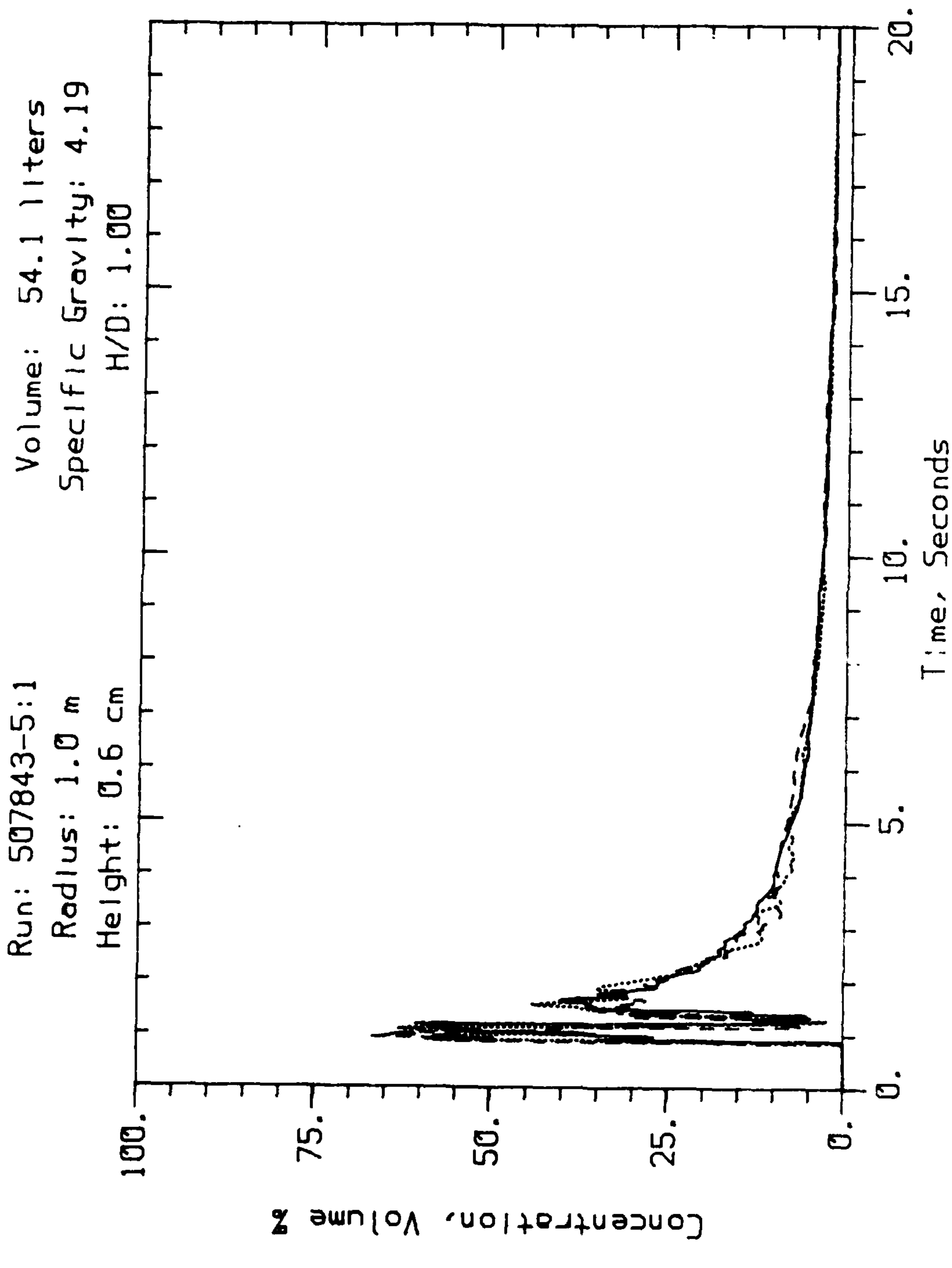

Run: 501842-4:4
Radius: 2.0 m
Height: 4.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds
0.
5.
10.
15.
20.


Run: 501842-4:5
Radius: 2.0 m
Height: 8.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.0
1.0
2.0
3.0
4.0
0.
5.
10.
15.
20.

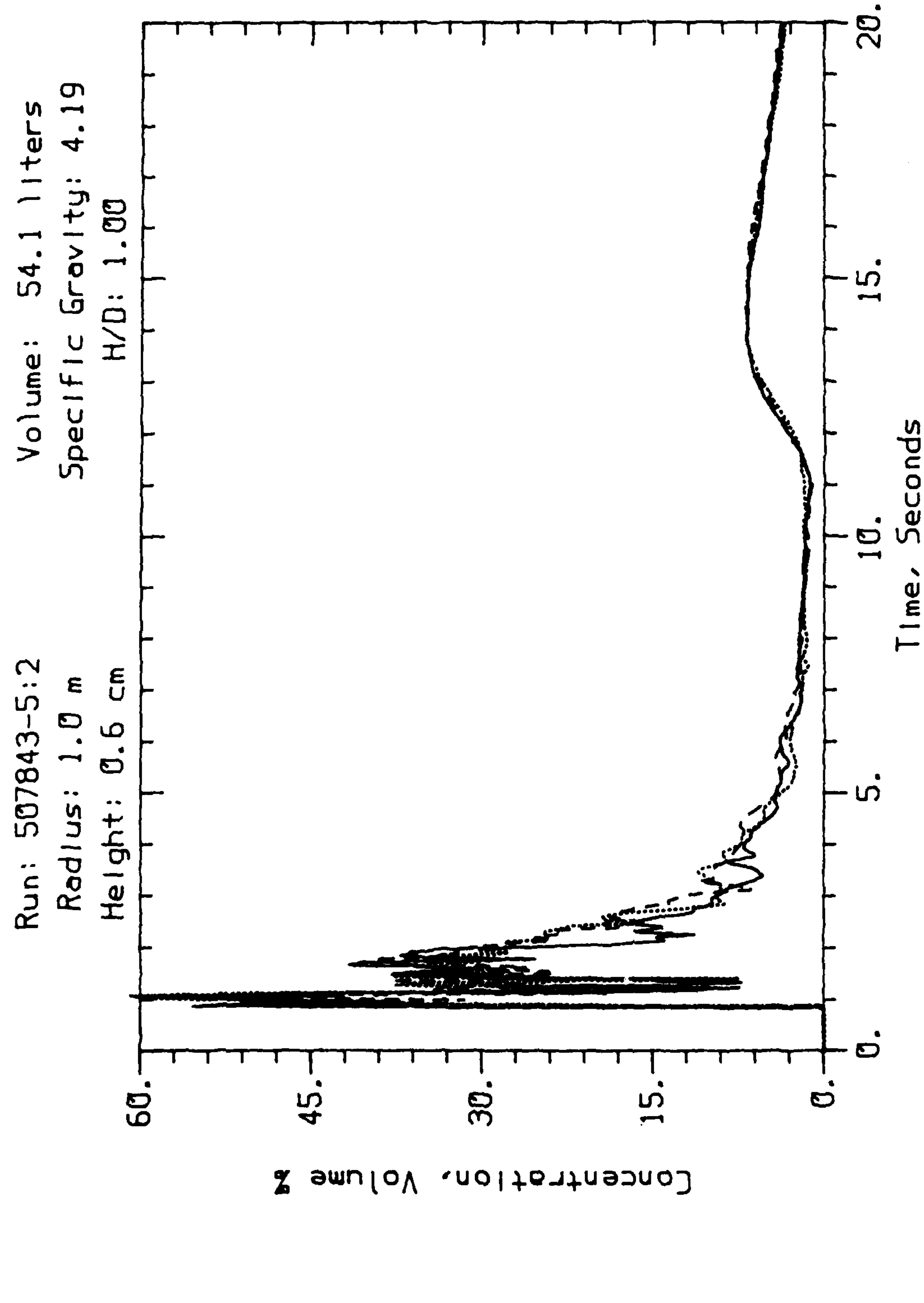

Run: 501842-4:6
Radius: 2.6 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.


Run: 501842-4:7
Radius: 2.6 m
Height: 4.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.
5.
10.
15.
20.
Concentration, Volume %

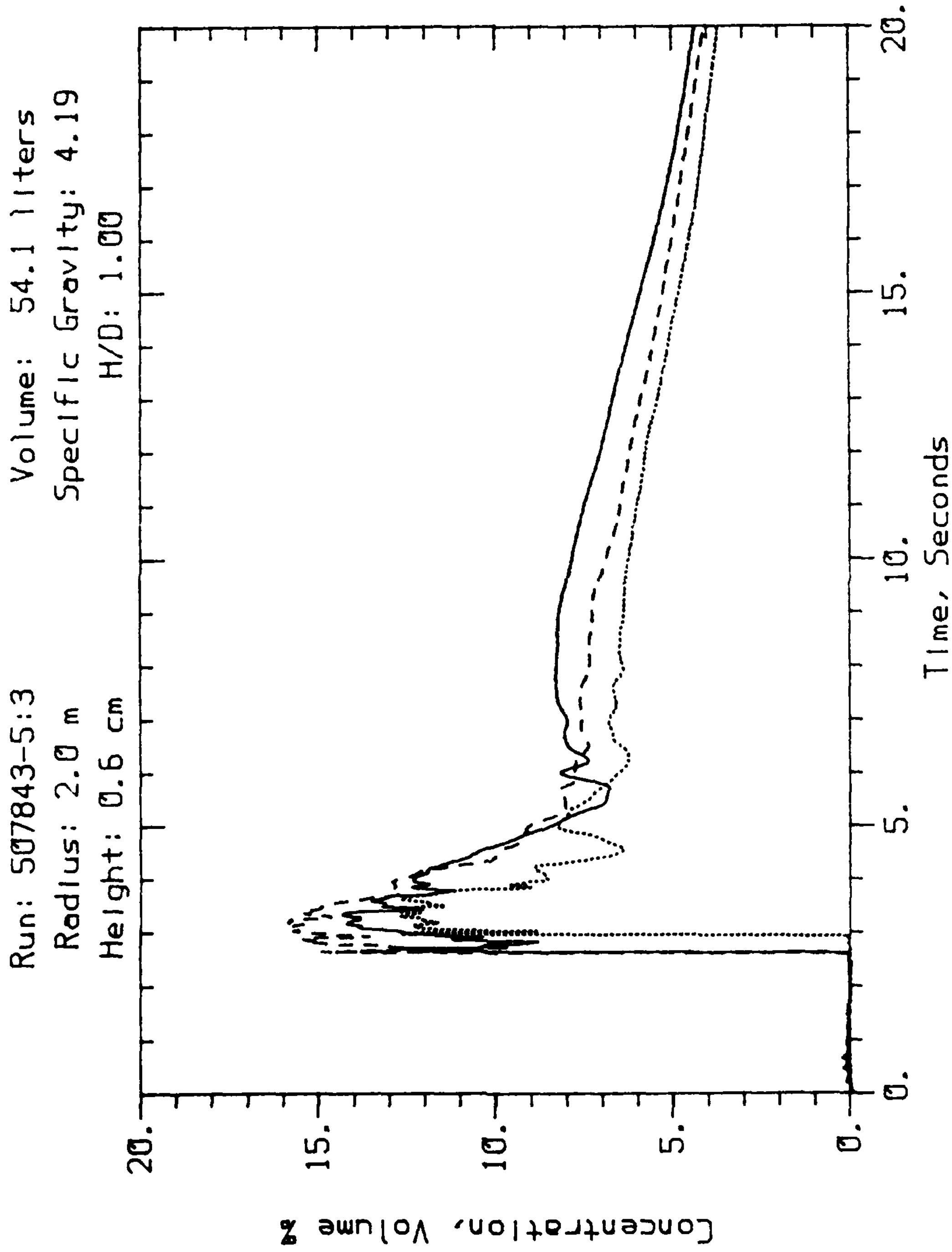

Run: 501842-4:8
Radius: 2.6 m
Height: 8.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
0.
10.
15.
20.
Time, Seconds

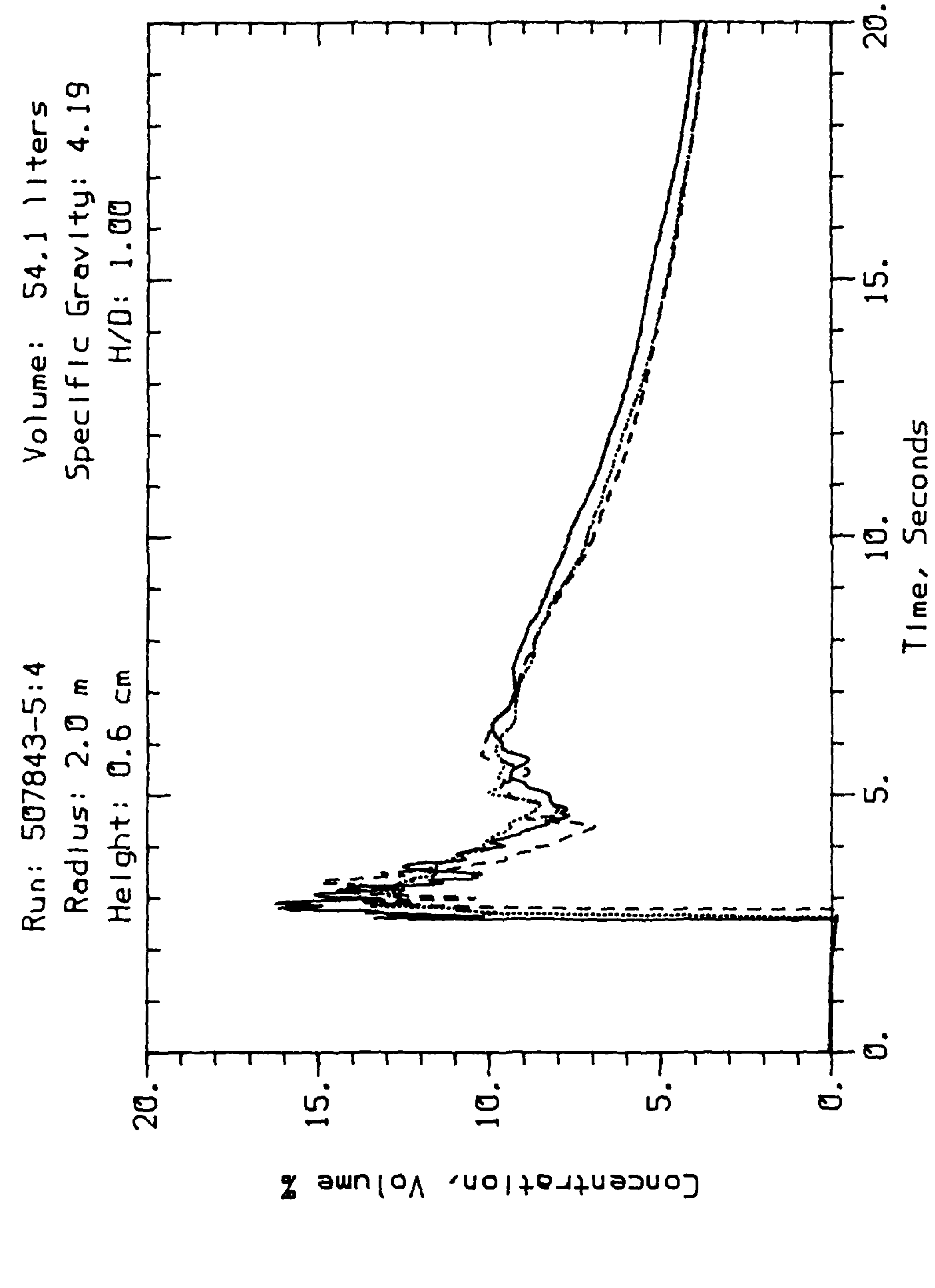


Run: 507843-5:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
100.
75.
50.
25.
0.
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

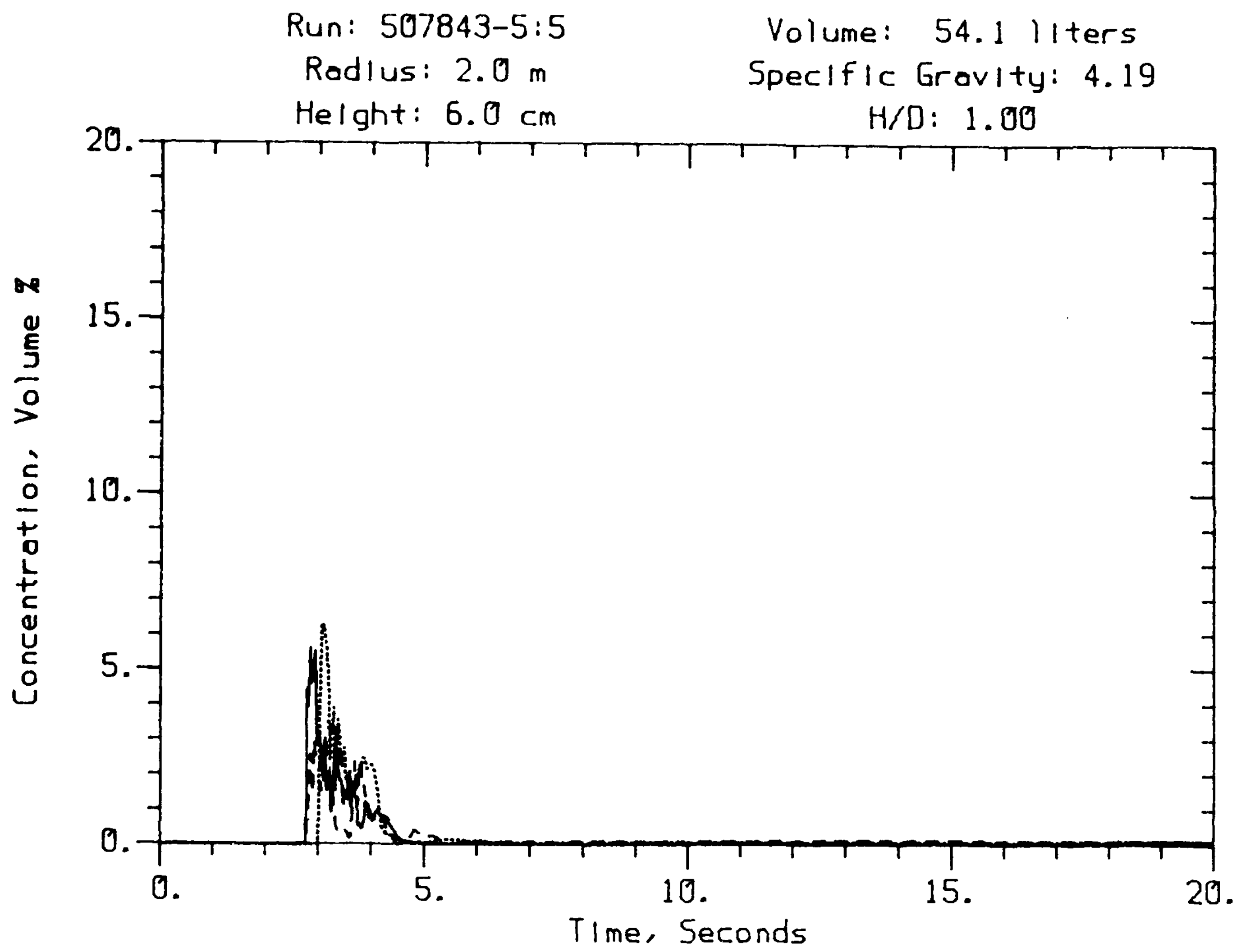


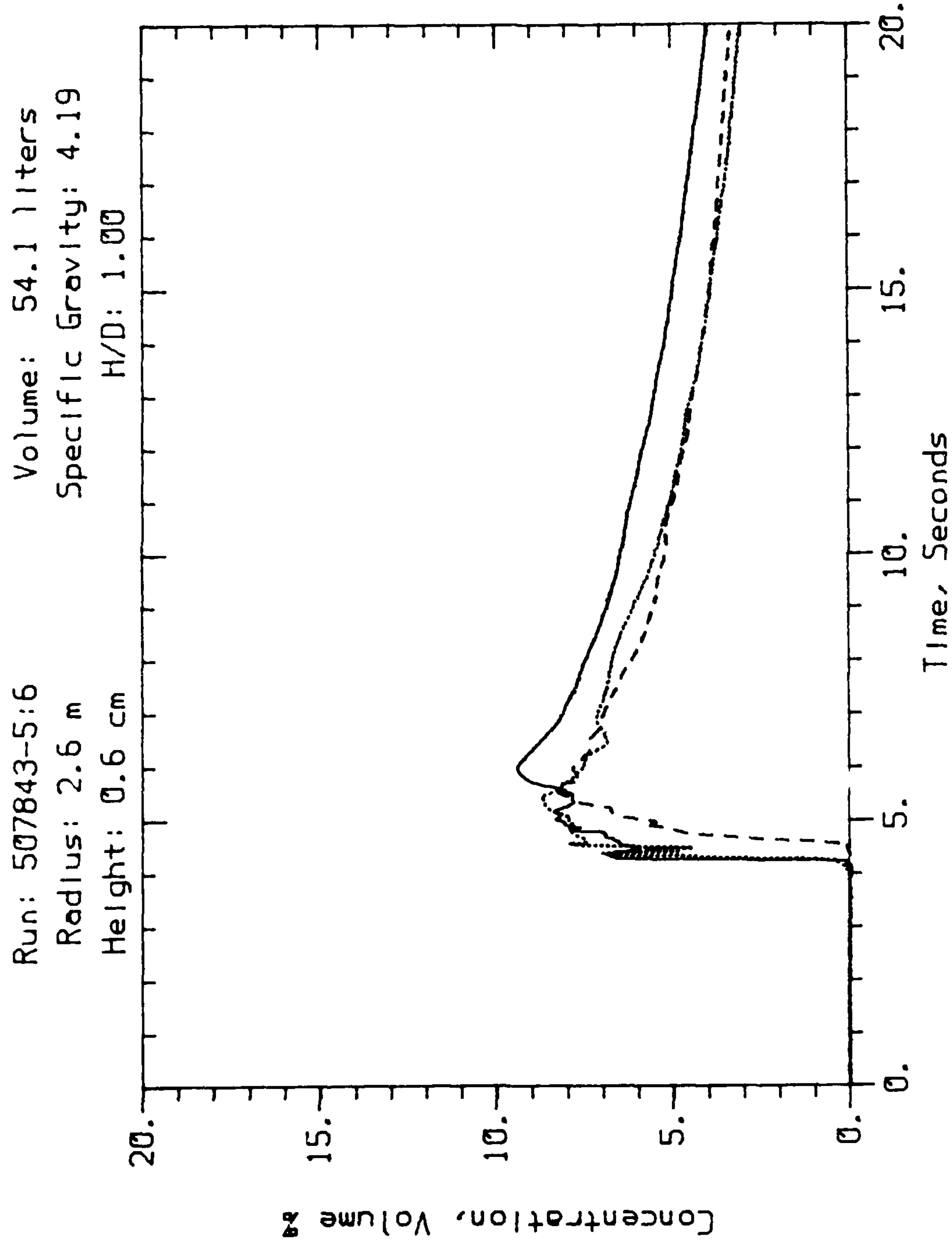
Run: 507843-5:2
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
60.
45.
30.
15.
0.
Time, Seconds
0.
5.
10.
15.
20.

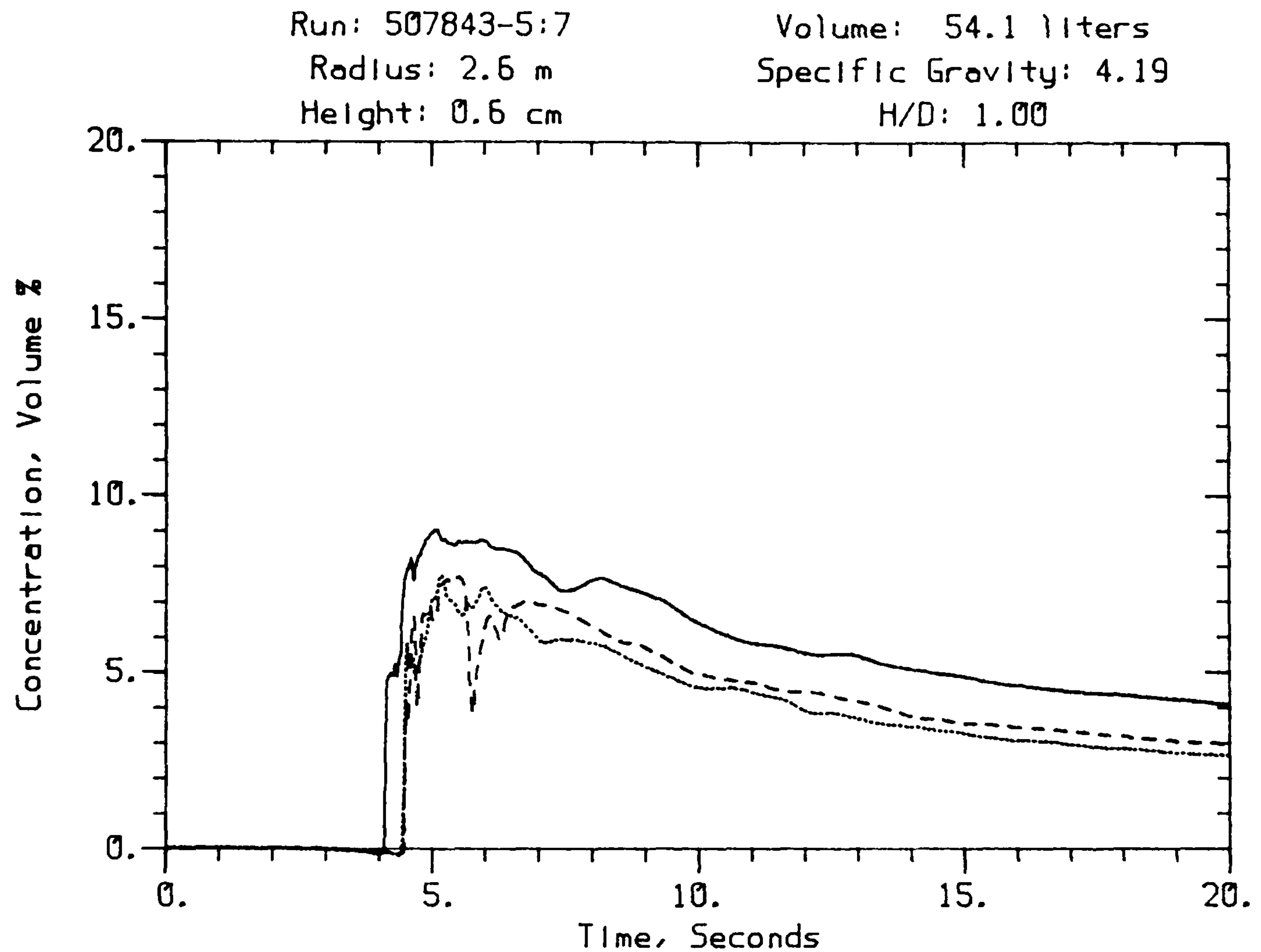

Run: 507843-5:3
Radius: 2.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

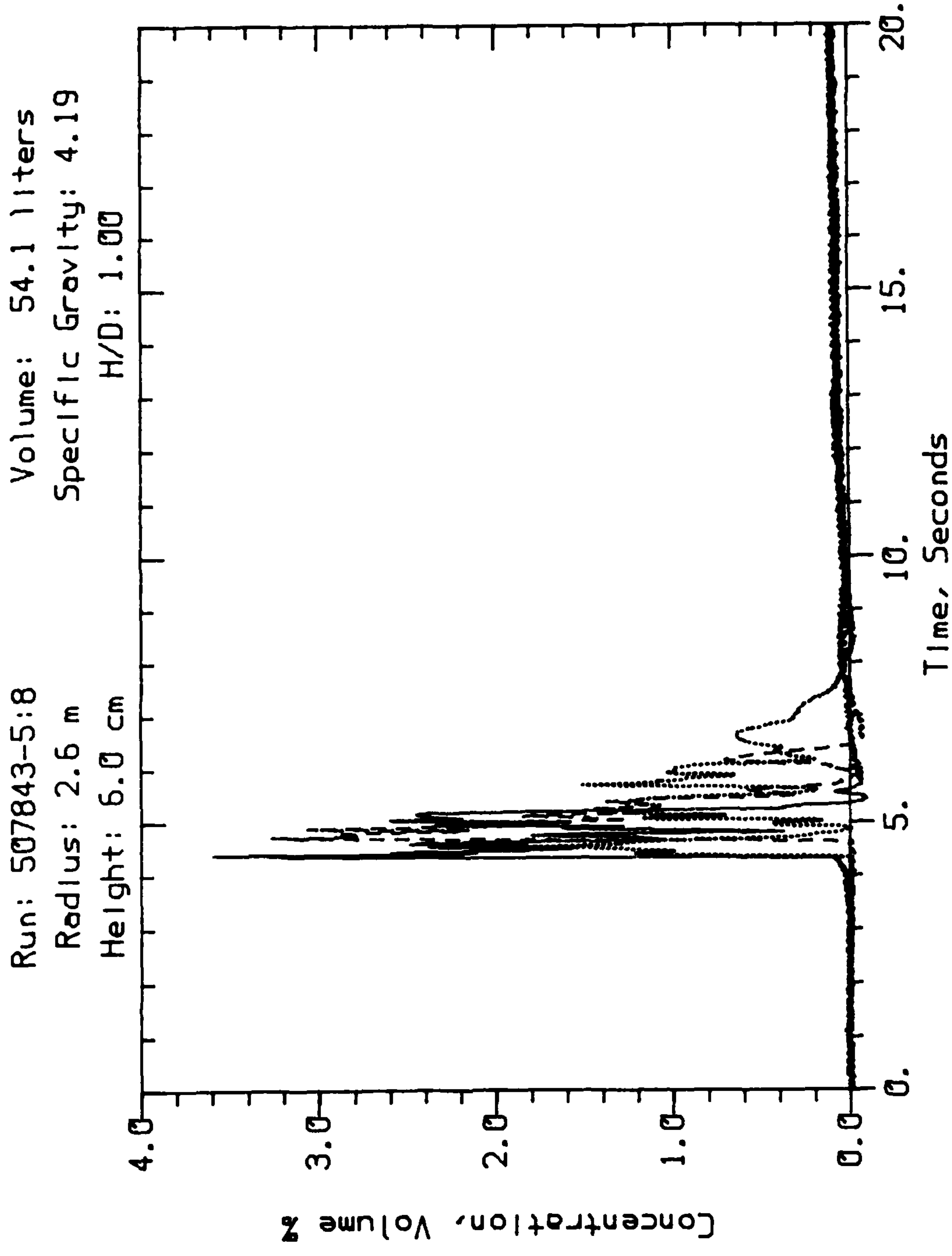


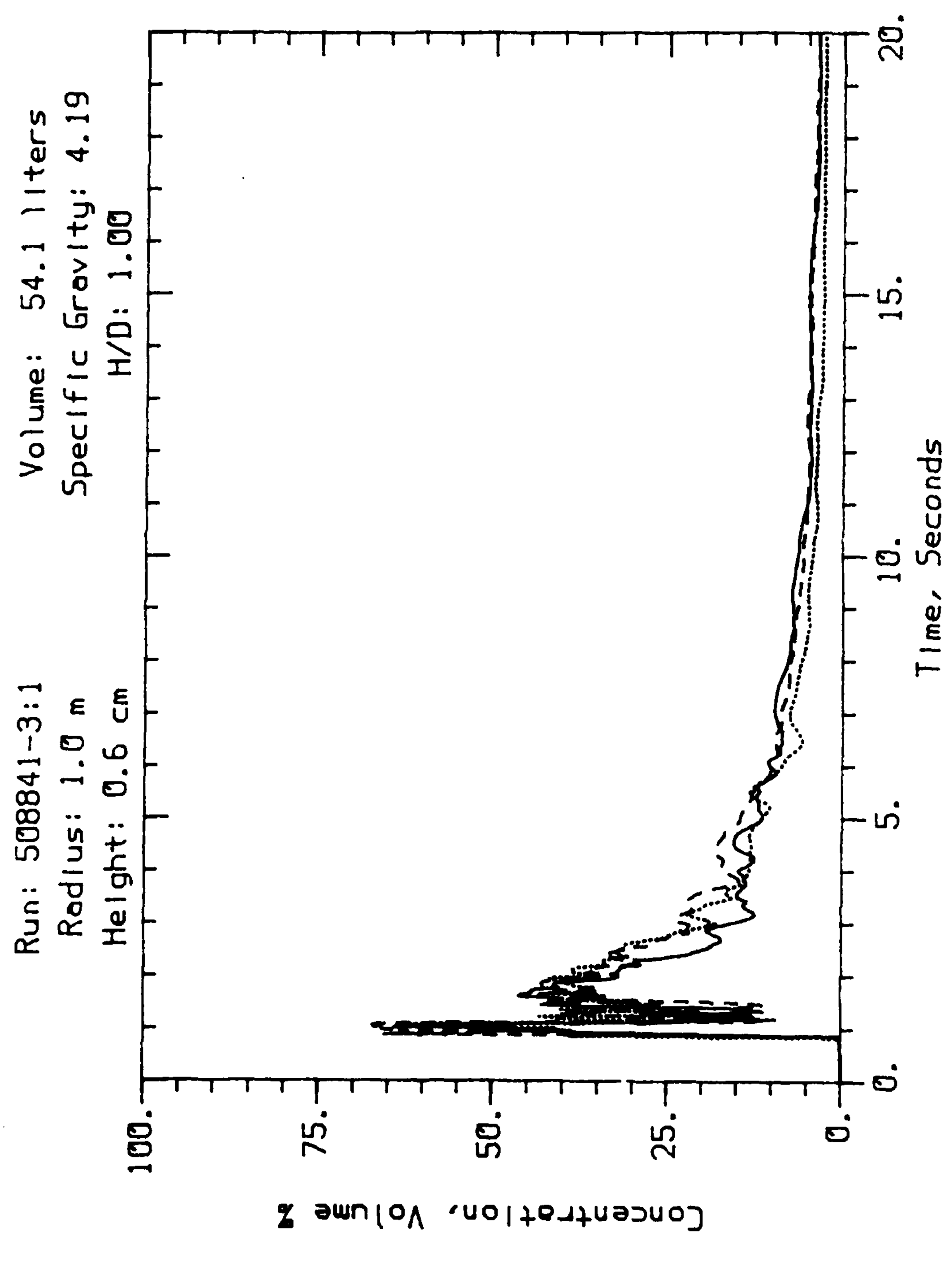
Run: 507843-5:4
Radius: 2.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

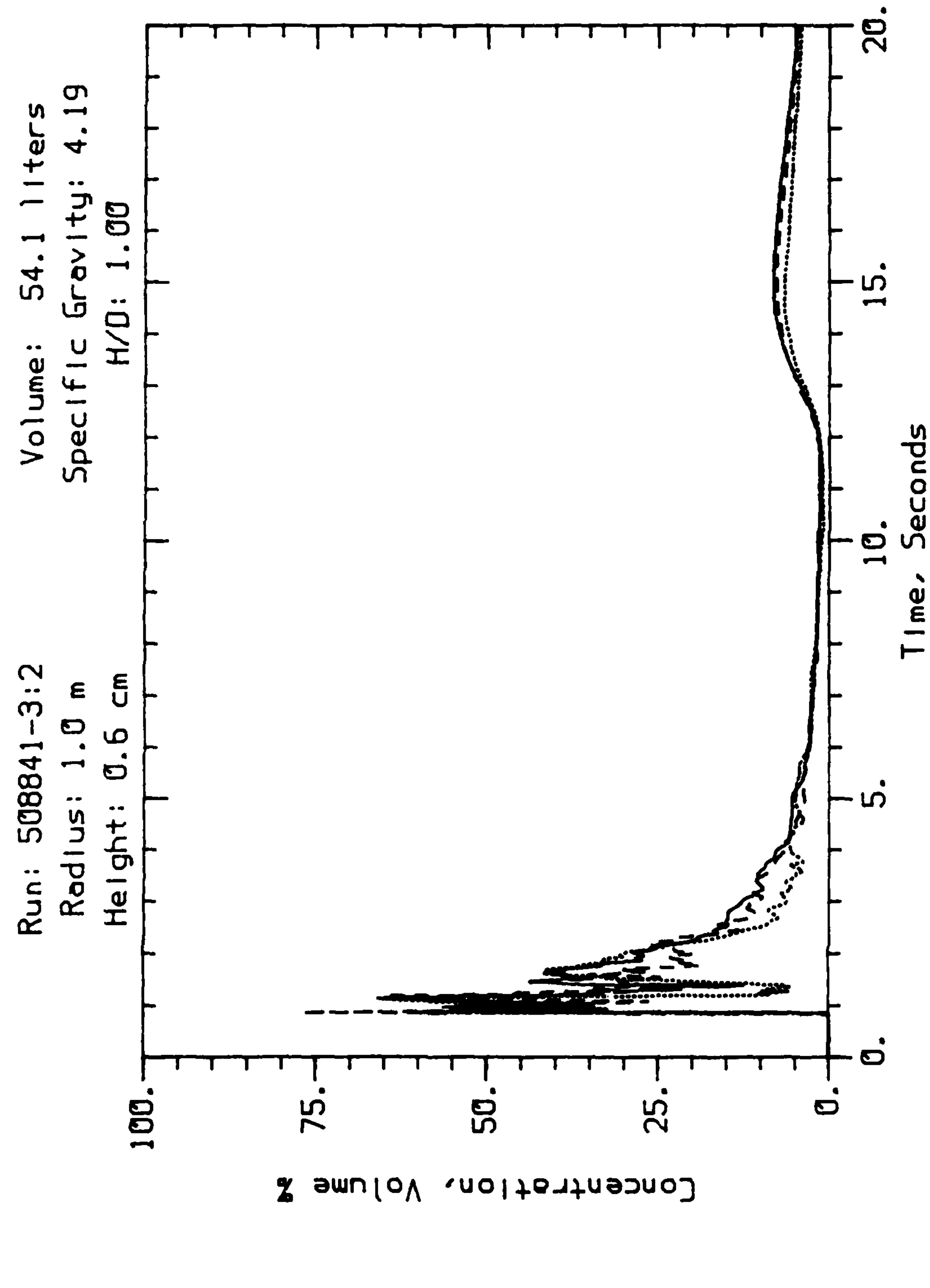

Run: 507843-5:5
Radius: 2.0 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.


Run: 507843-5:6
Radius: 2.6 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

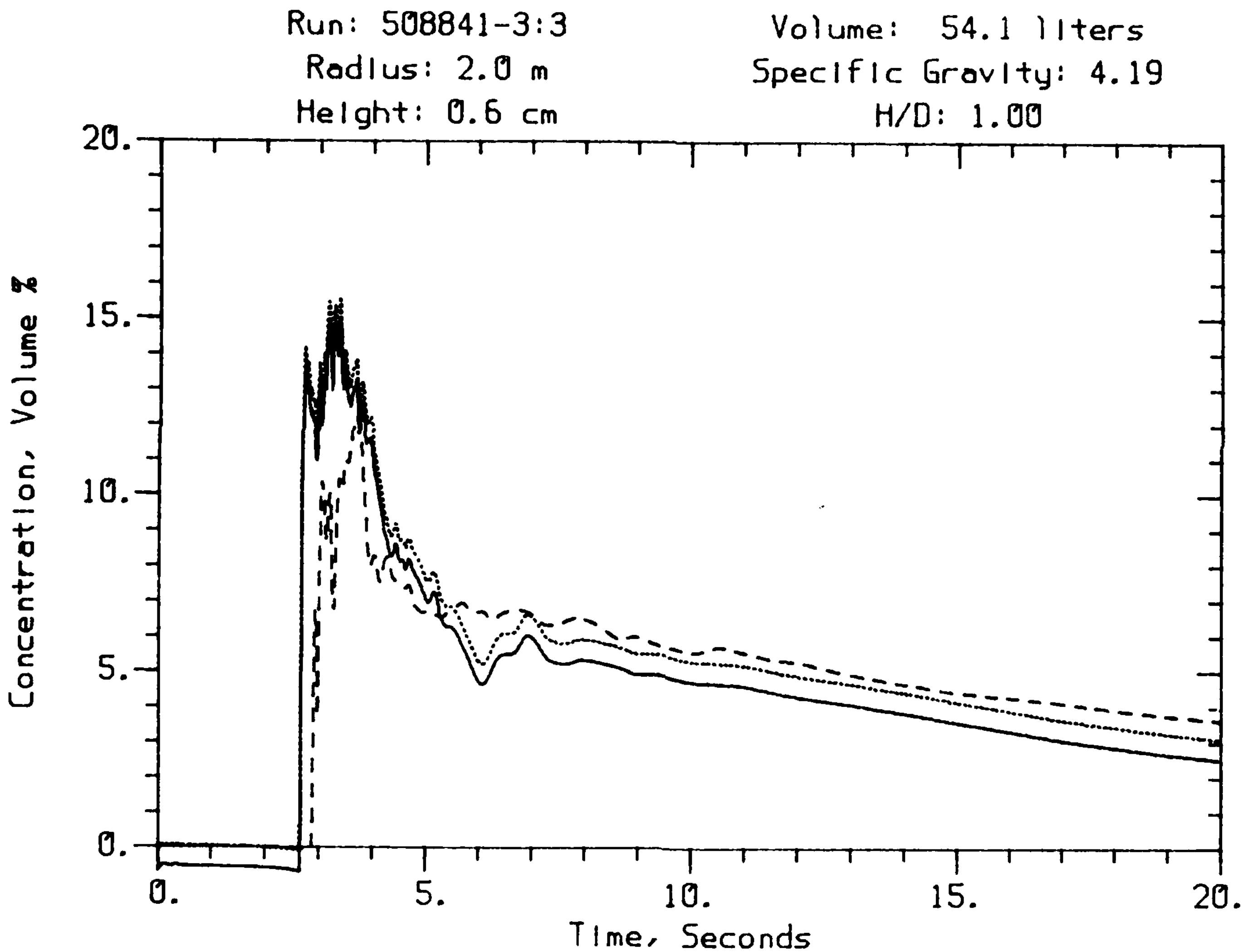

Run: 507843-5:7
Radius: 2.6 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

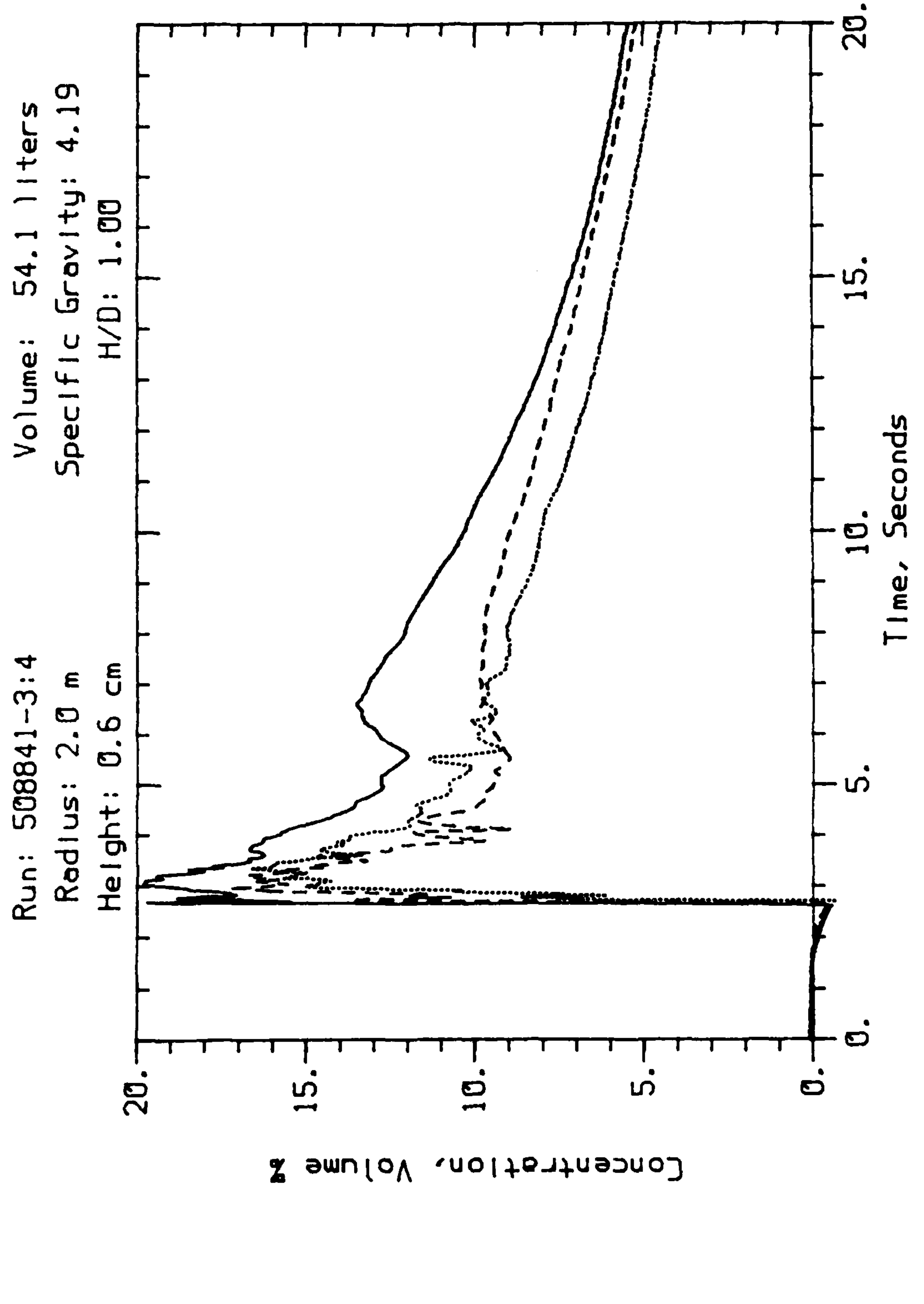

Run: 507843-5:8
Radius: 2.6 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.0
1.0
2.0
3.0
4.0
0.
5.
10.
15.
20.

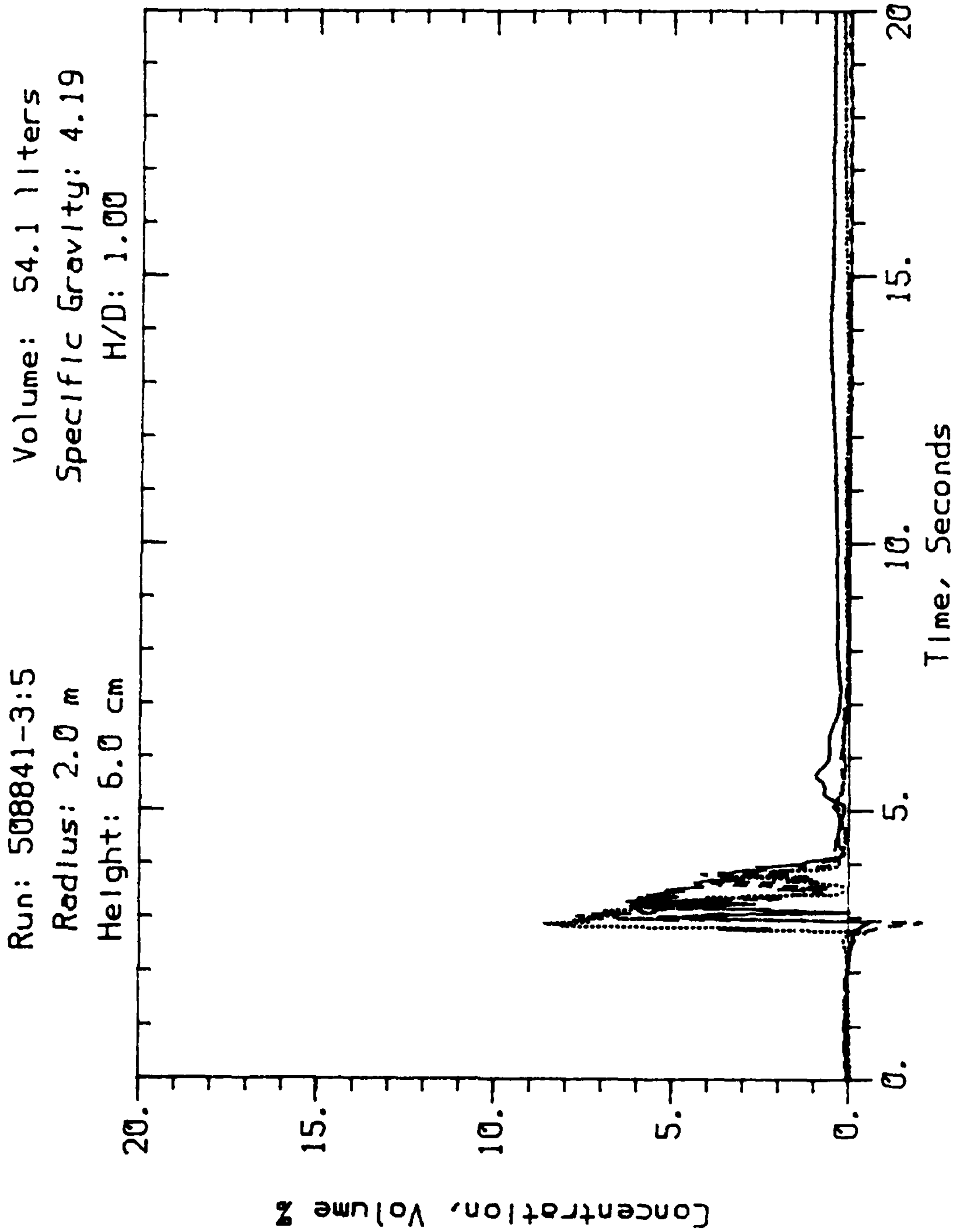

Run: 508841-3:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
100.
75.
50.
25.
0.
Time, Seconds
0.
5.
10.
15.
20.

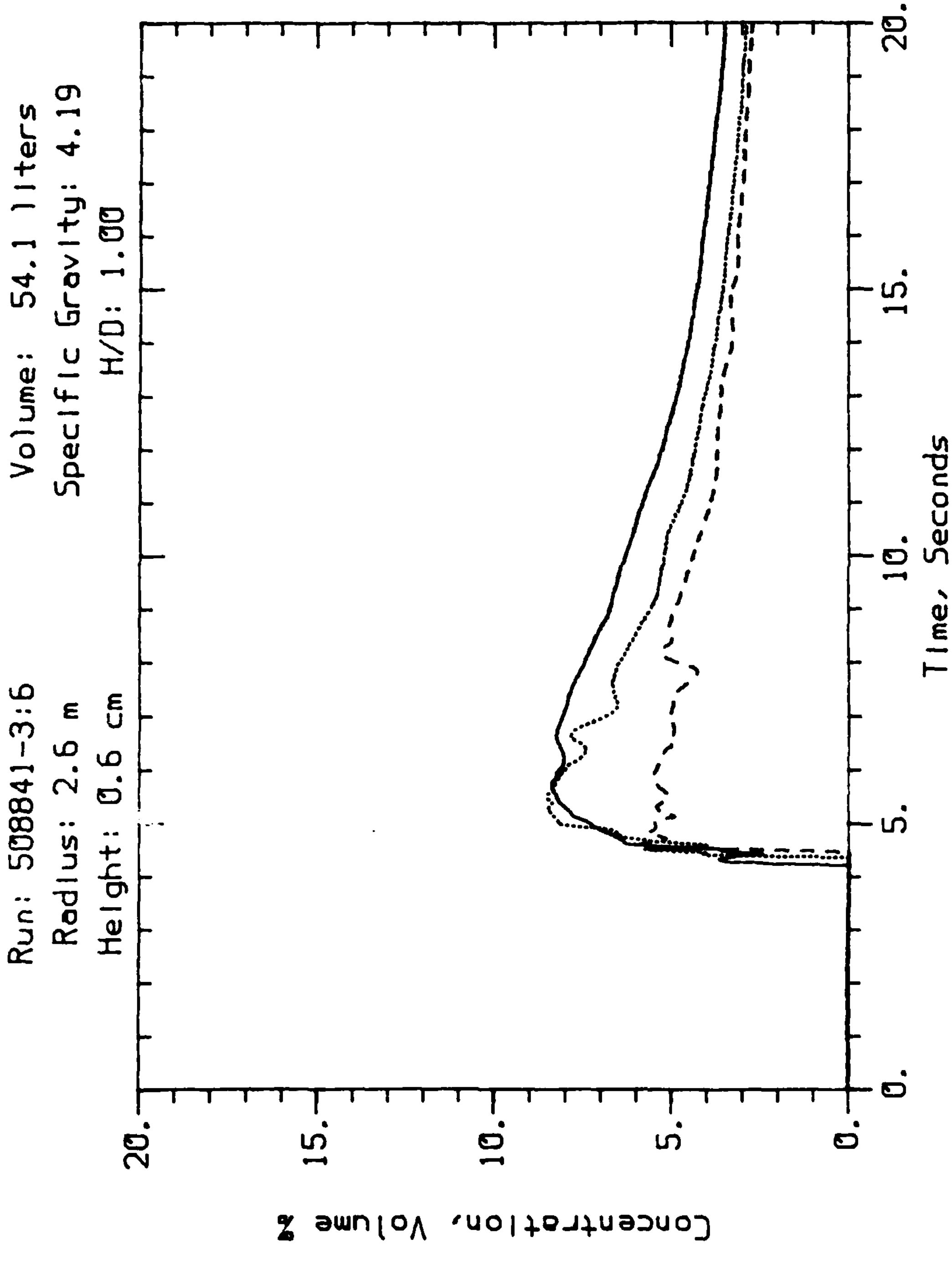


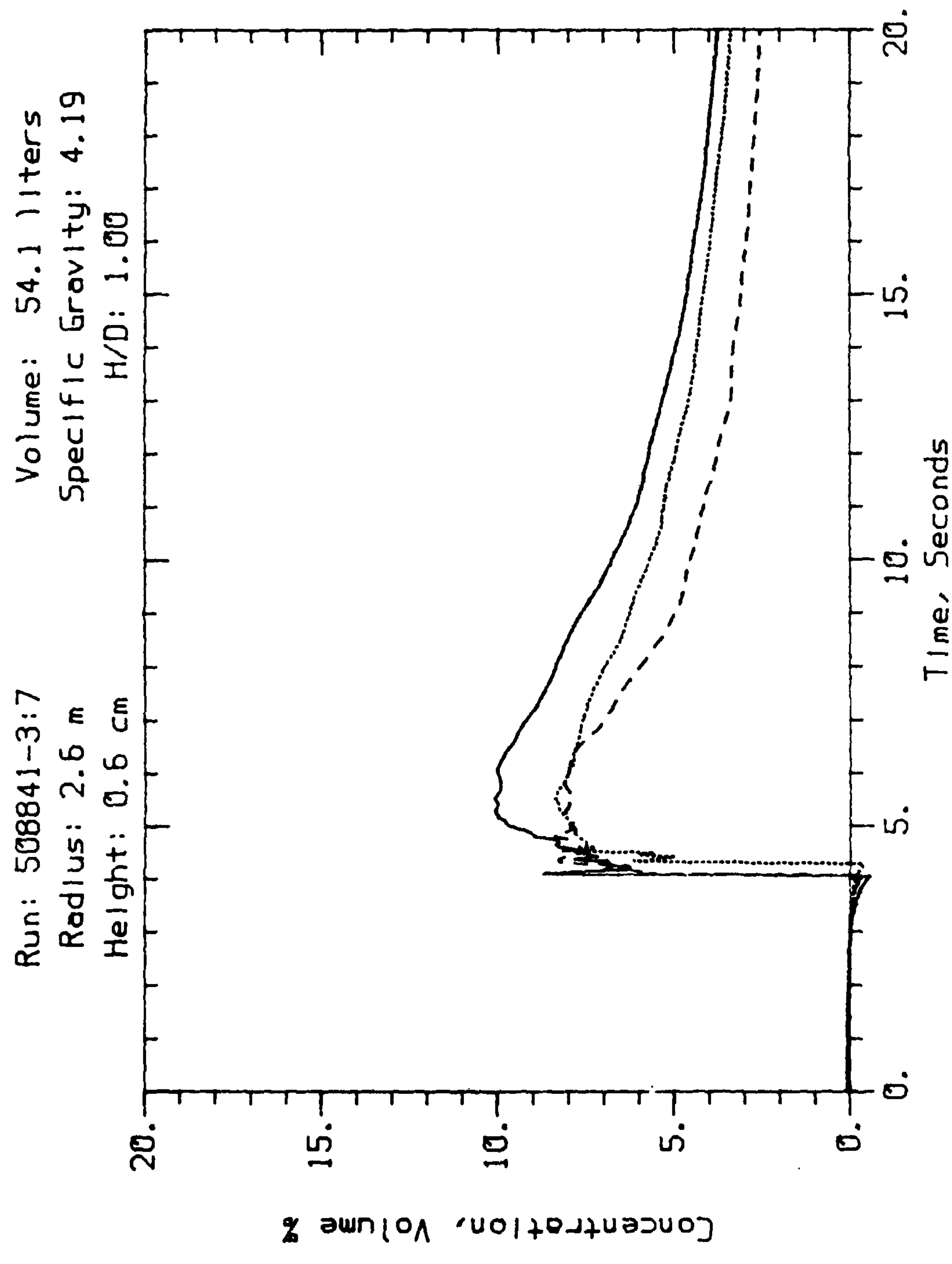
Run: 508841-3:2
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.
25.
50.
75.
100.
0.
5.
10.
15.
20.
Time, Seconds

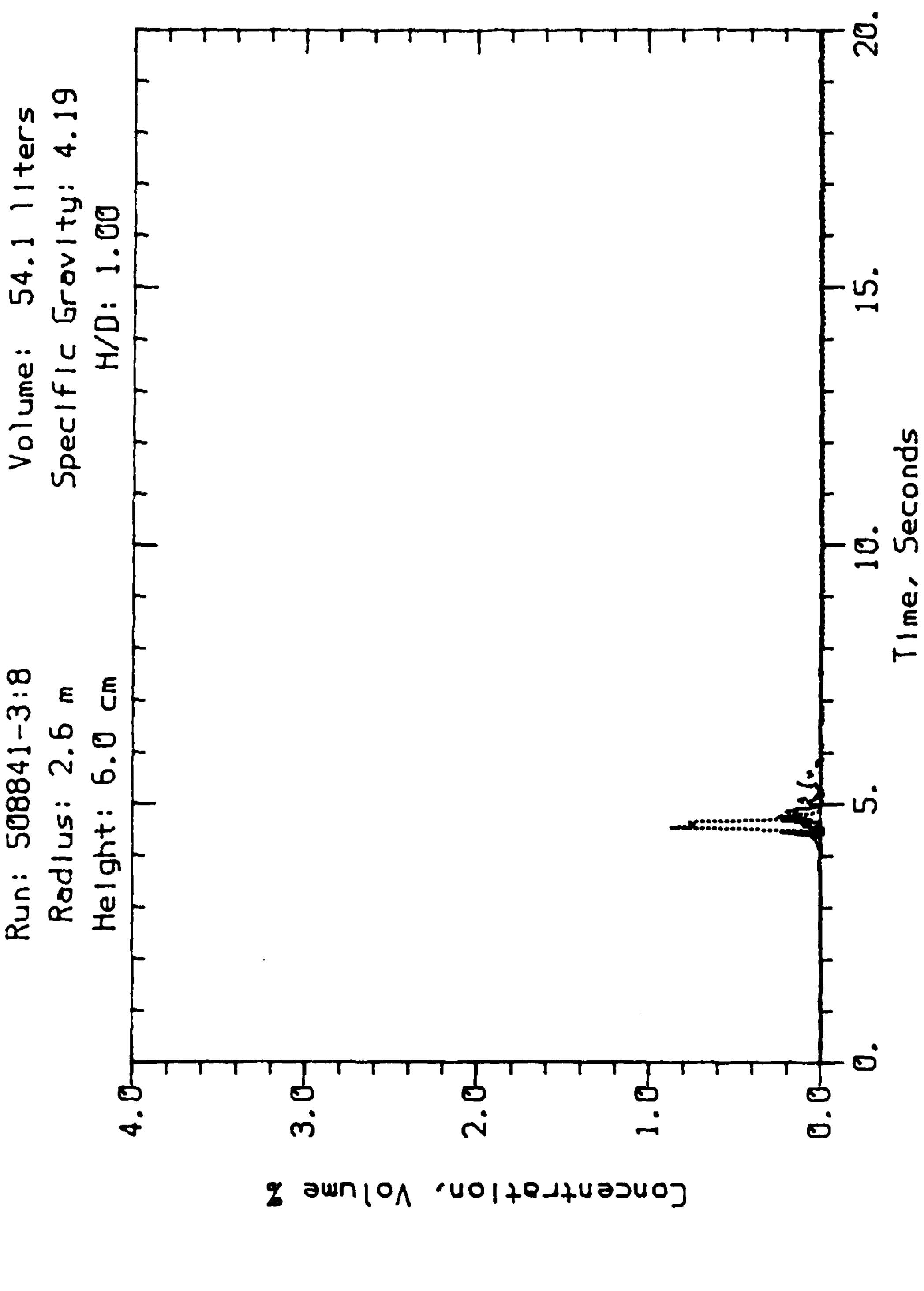

Run: 508841-3:3
Radius: 2.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

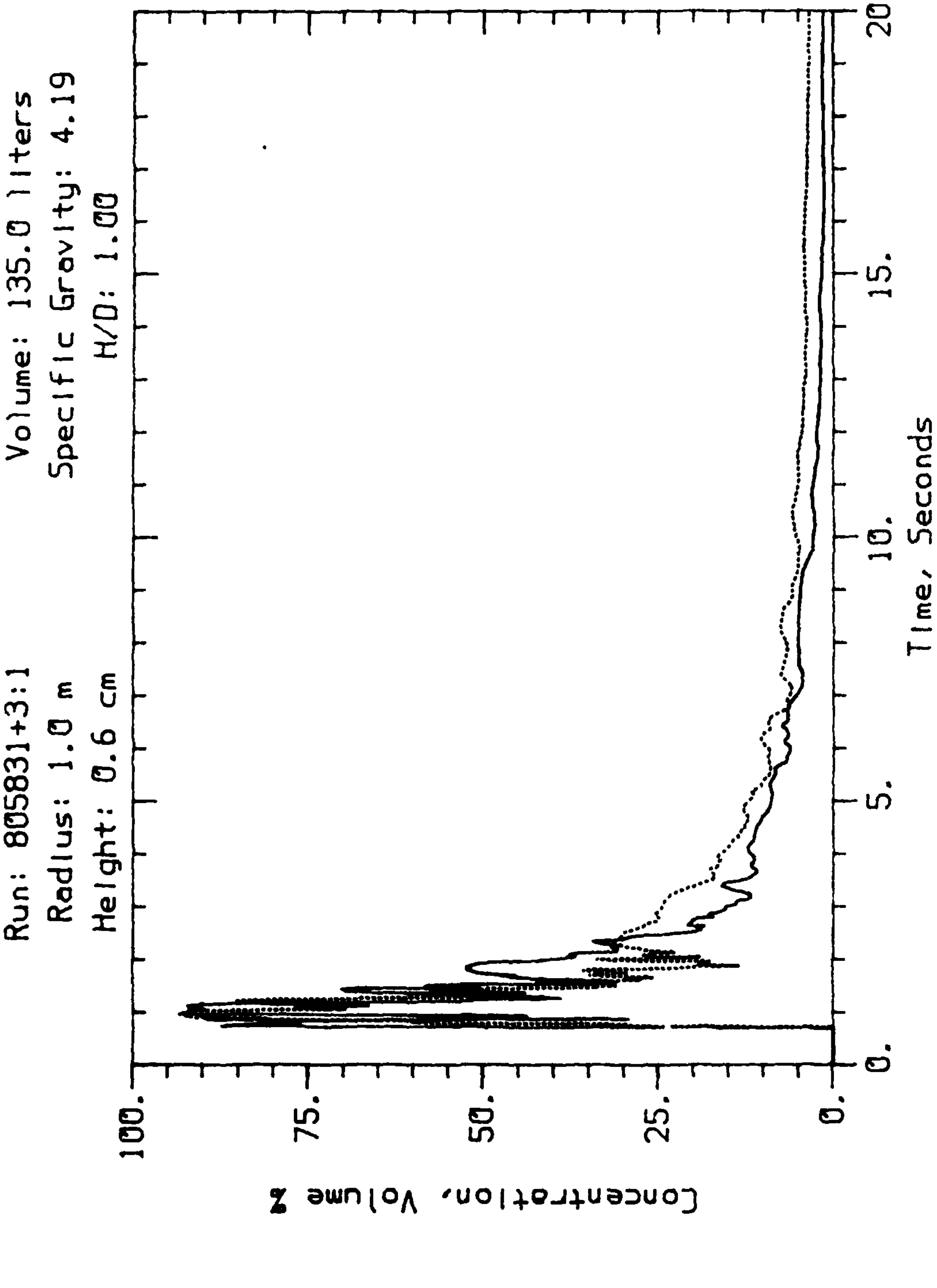

Run: 508841-3:4
Radius: 2.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

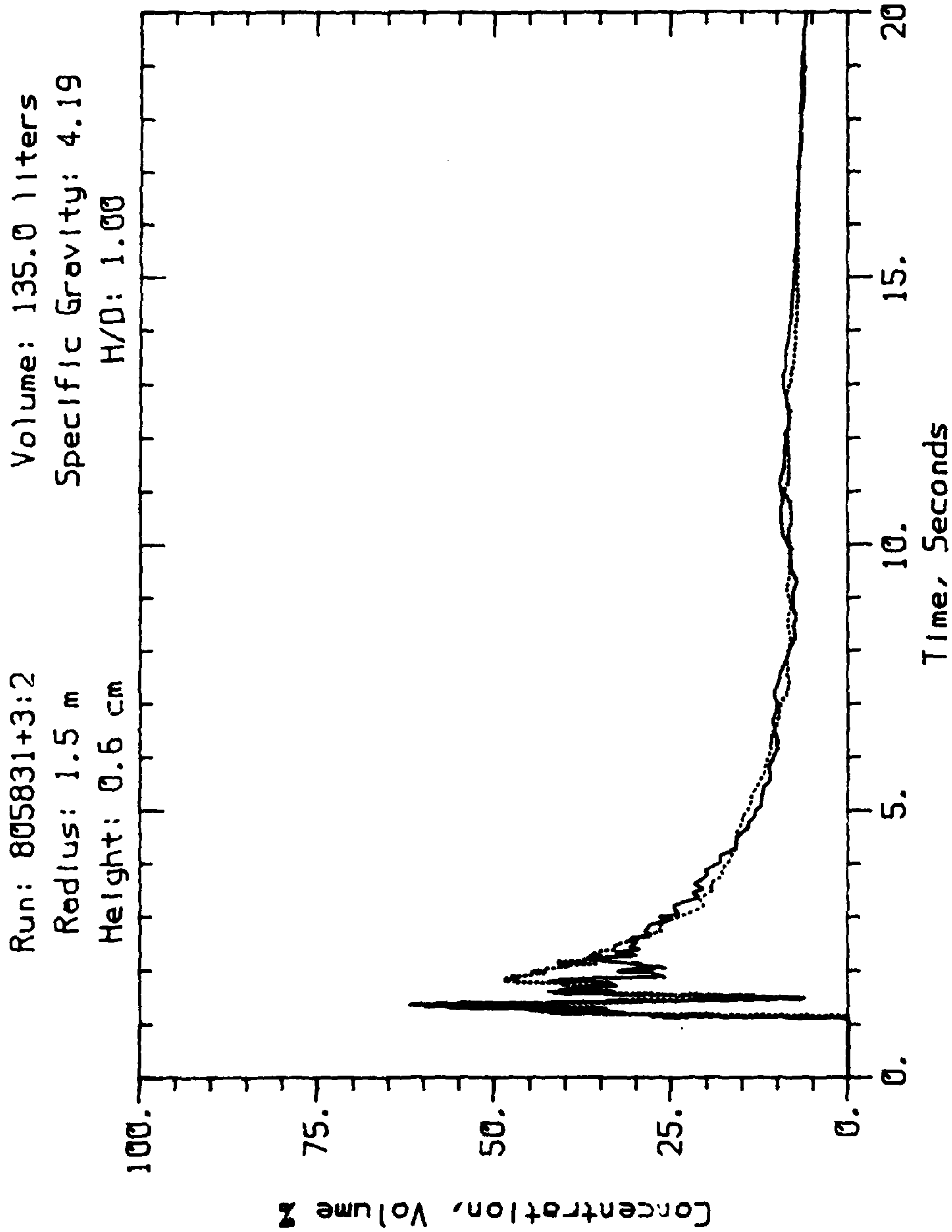

Run: 508841-3:5
Radius: 2.0 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.
5.
10.
15.
20.
Concentration, Volume %


Run: 508841-3:6
Radius: 2.6 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

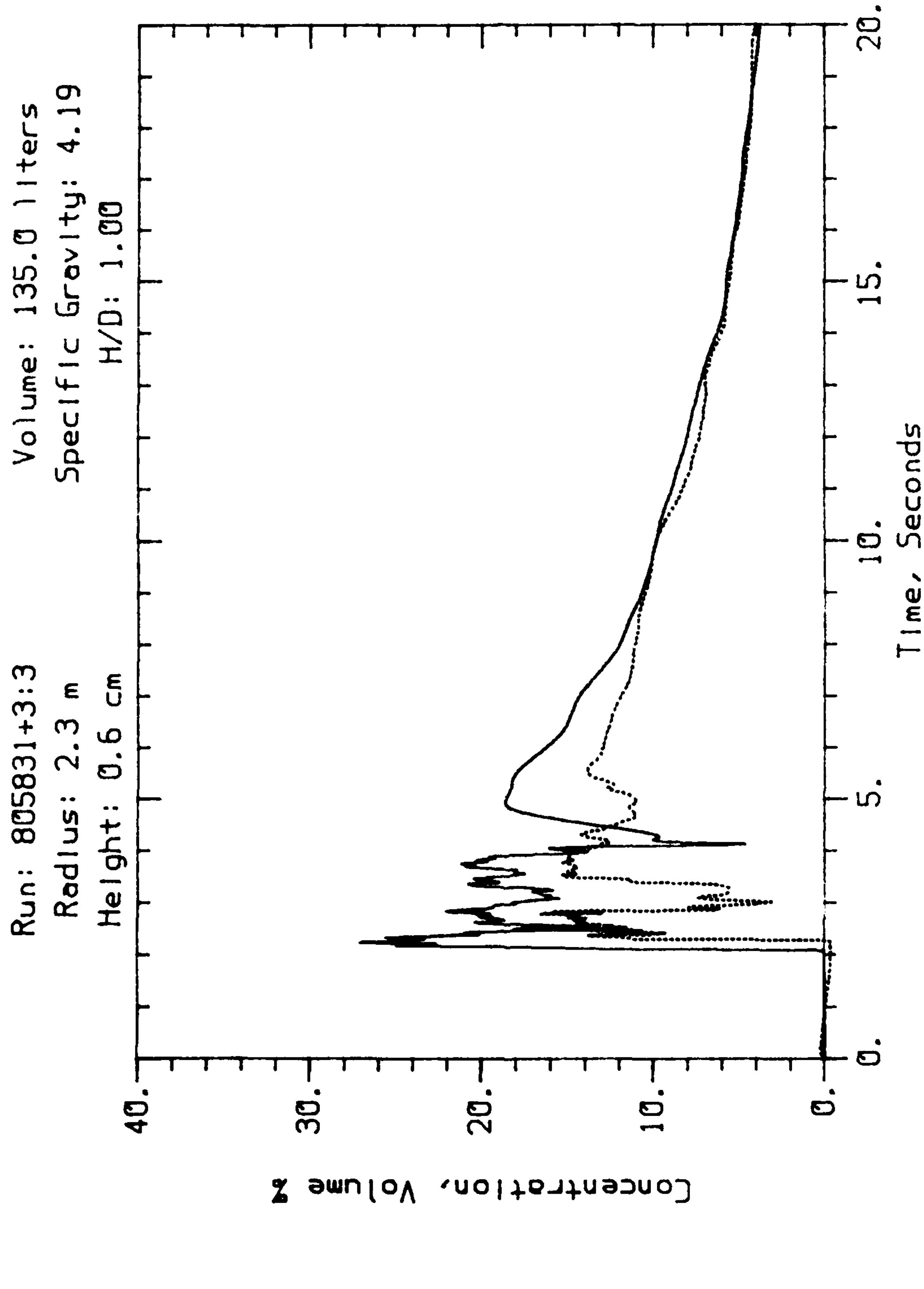

Run: 508841-3:7
Radius: 2.6 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
5.
10.
15.
20.

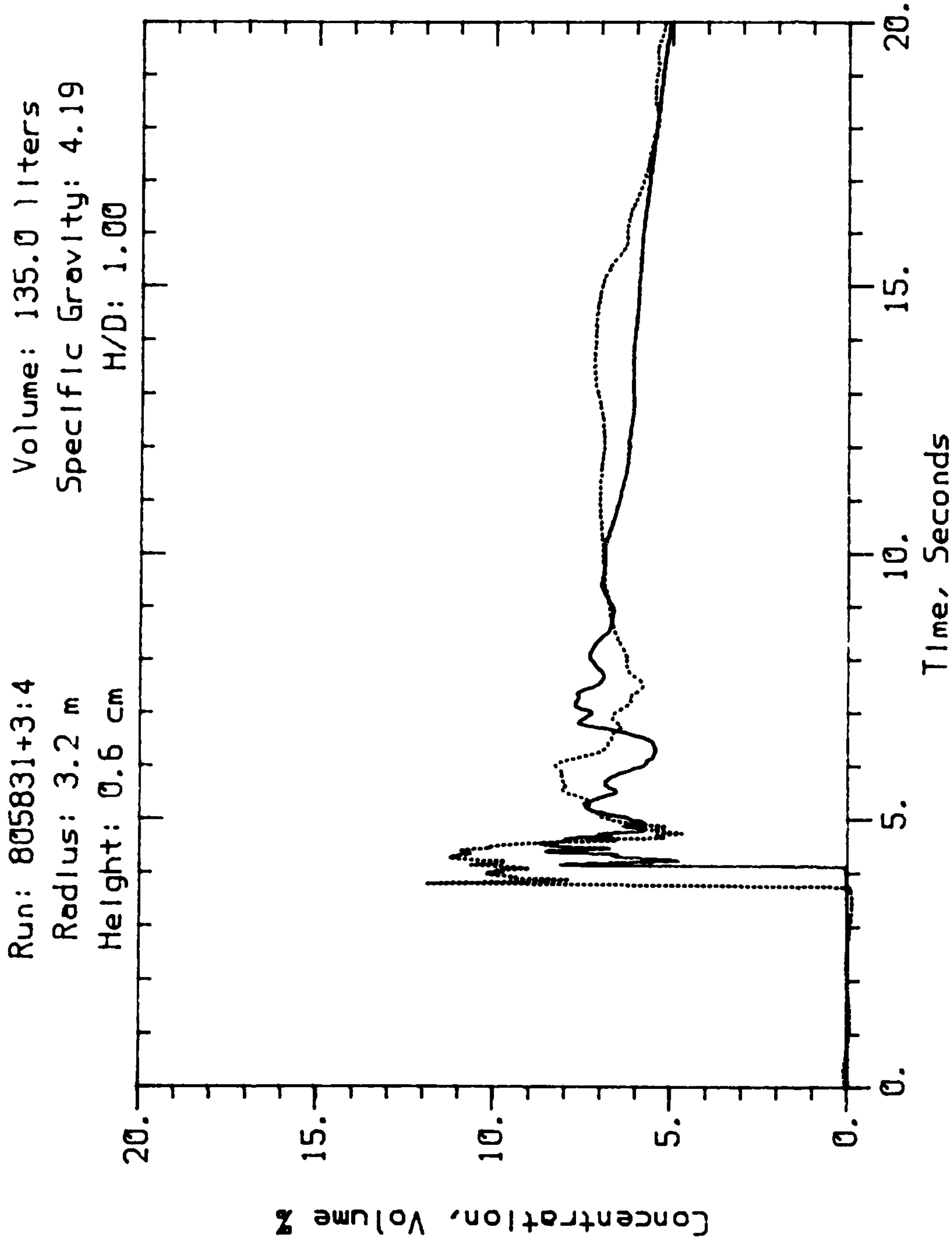

Run: 508841-3:8
Radius: 2.6 m
Height: 6.0 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
5.
10.
15.
20.


Run: 805831+3:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
100.
75.
50.
25.
0.
Time, Seconds
0.
5.
10.
15.
20.

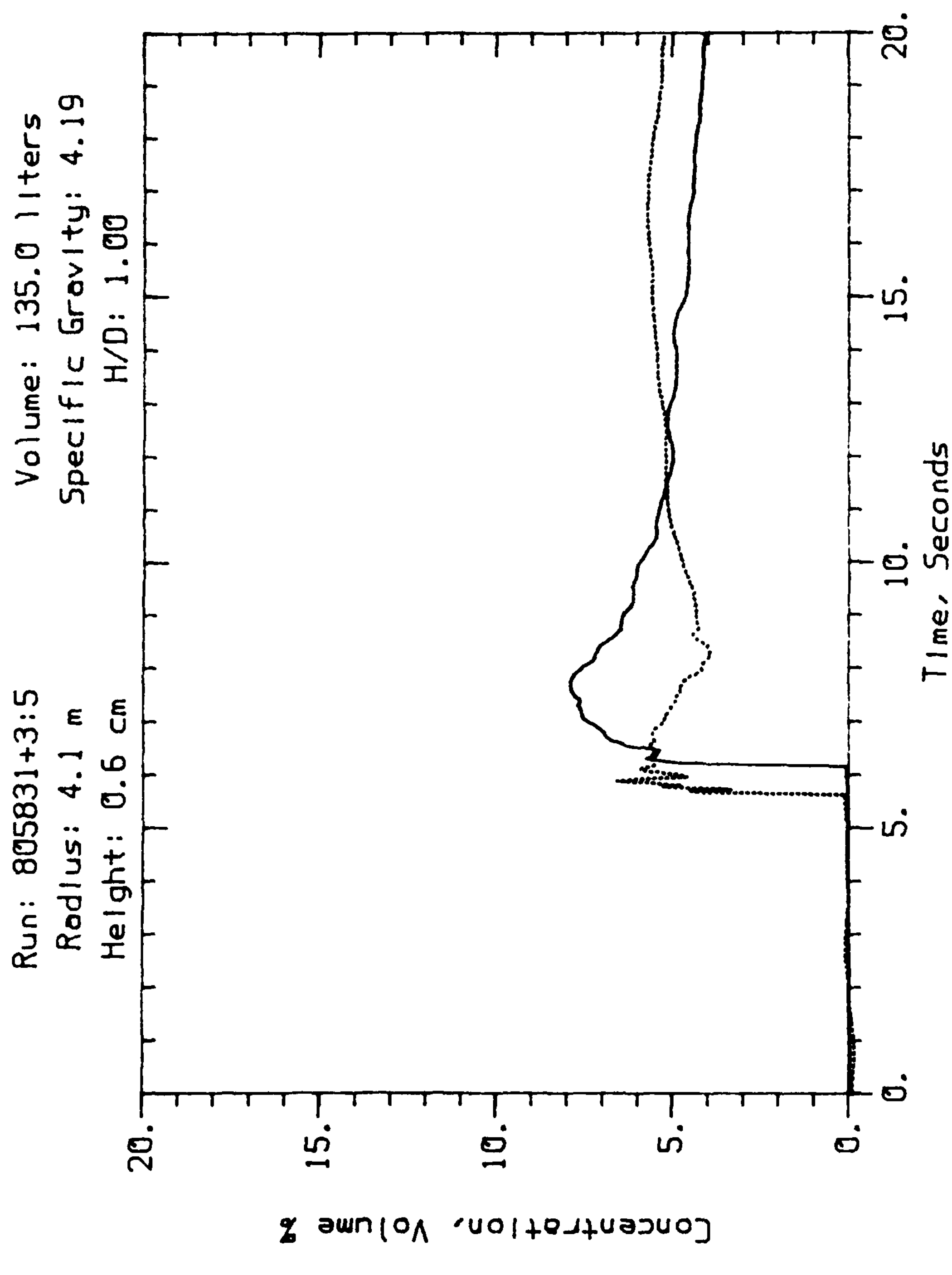


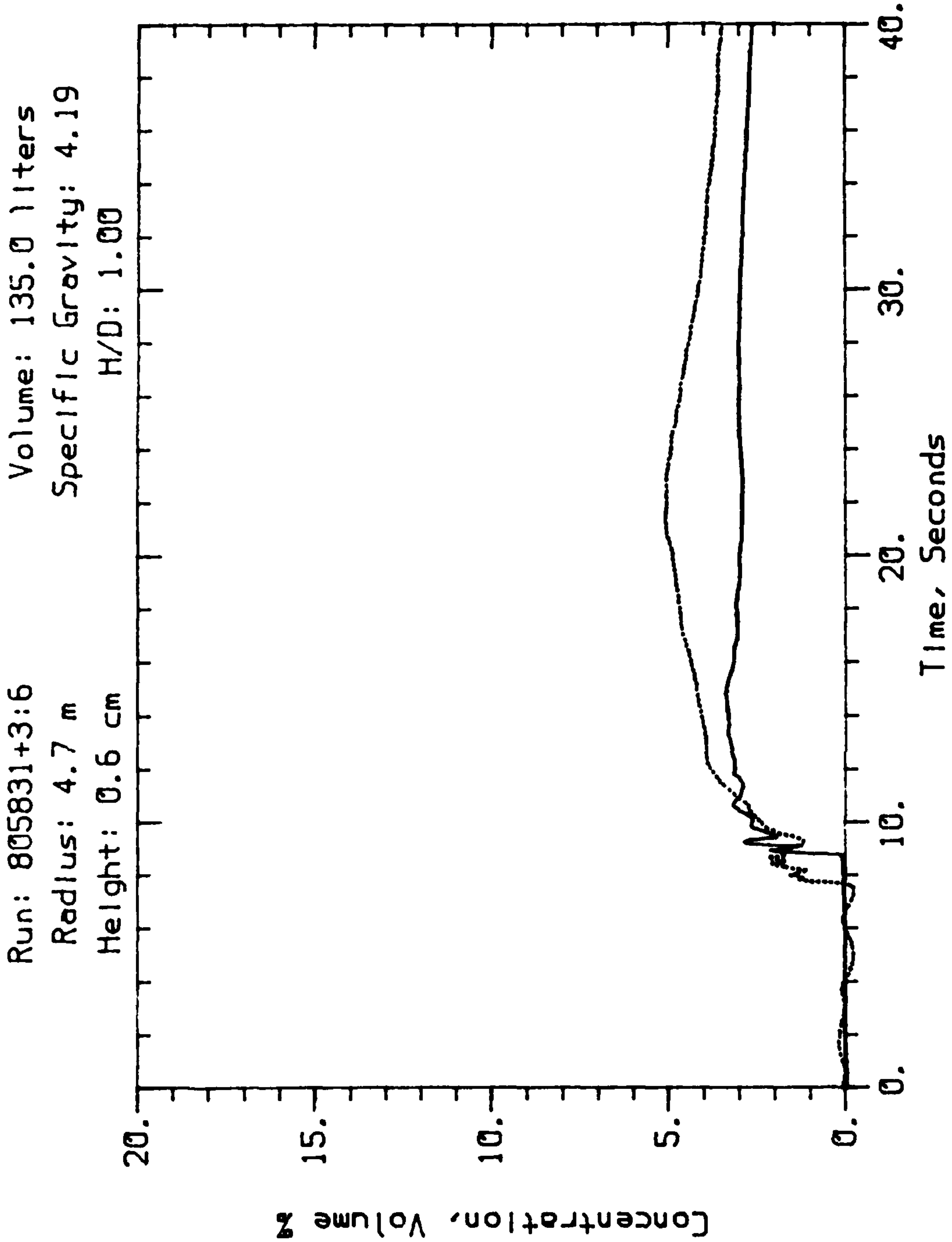
Run: 805831+3:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
100.
75.
50.
25.
0.
0.
5.
10.
15.
20.
Time, Seconds


Run: 805831+3:3
Radius: 2.3 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.
10.
20.
30.
40.
Concentration, Volume %

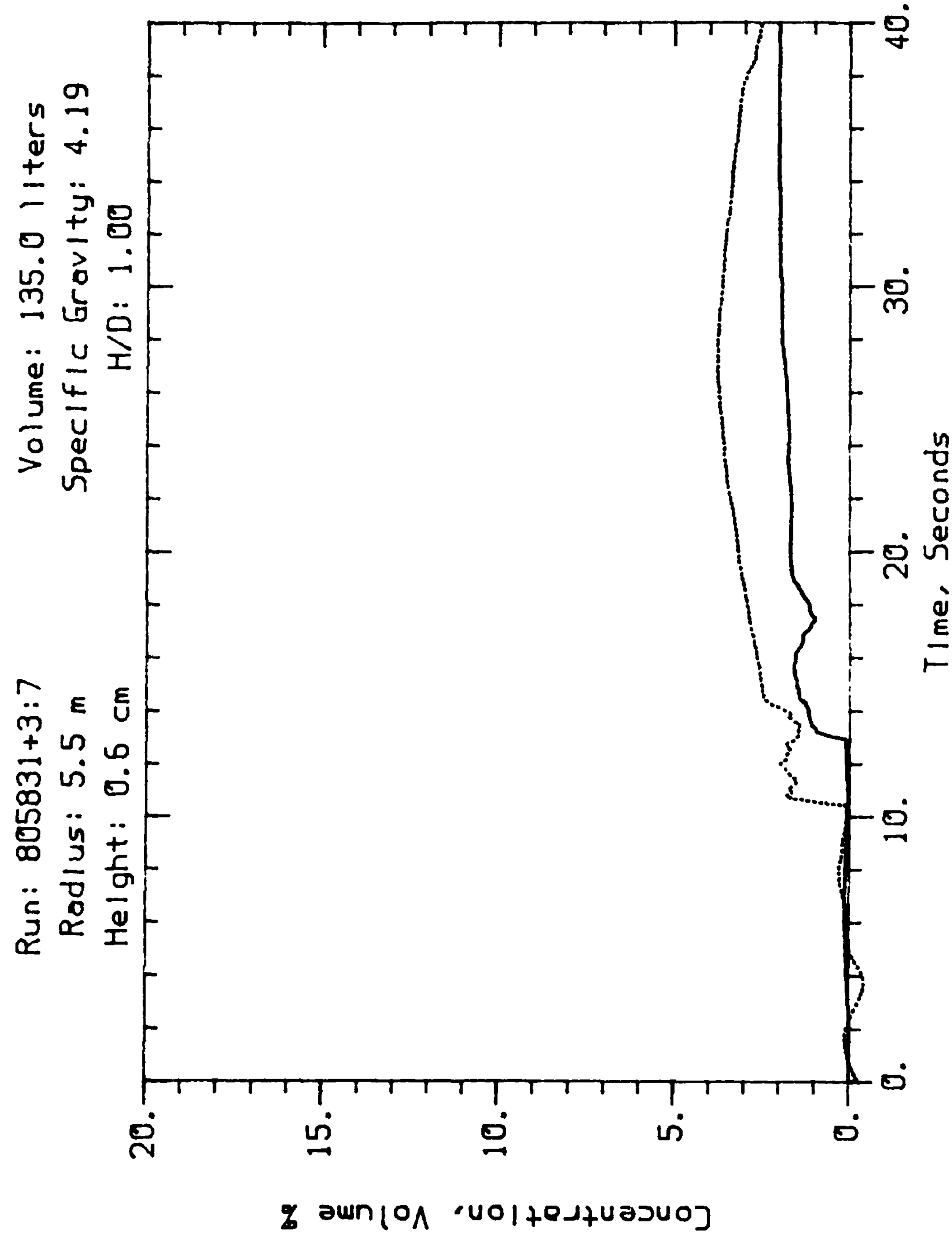


Run: 805831+3:4
Radius: 3.2 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds
0.
5.
10.
15.
20.

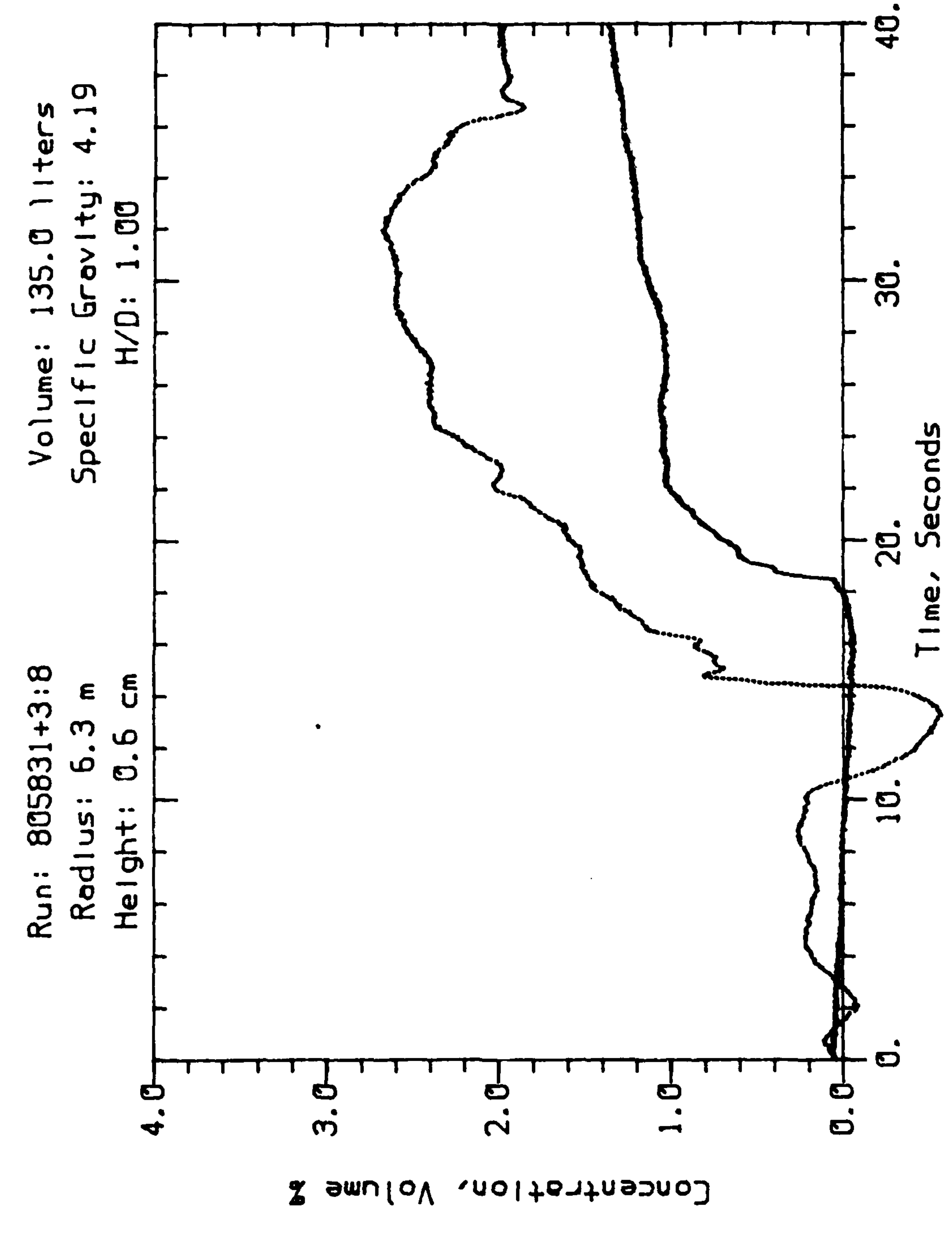

Run: 805831+3:5
Radius: 4.1 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.



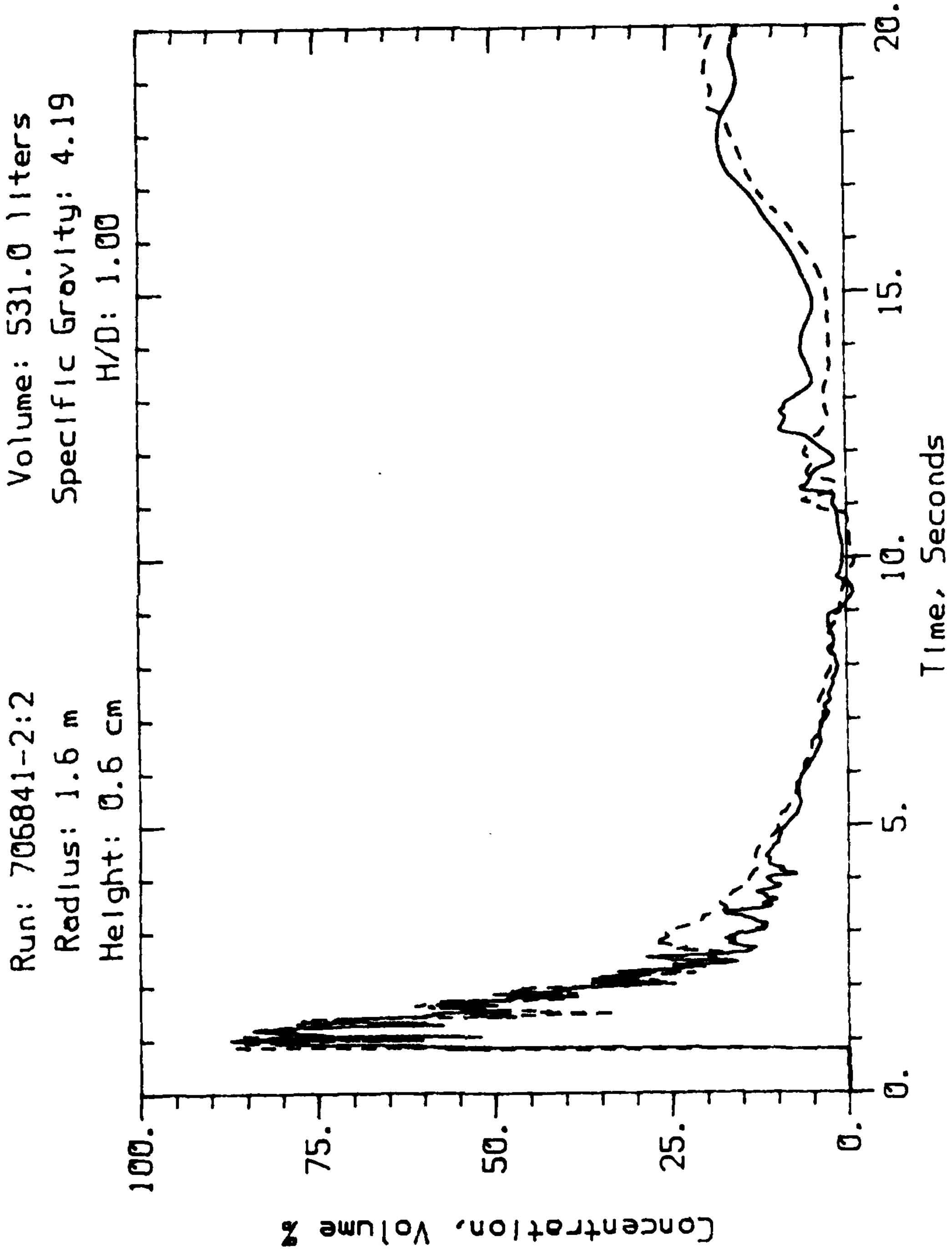
Run: 805831+3:6
Radius: 4.7 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
10.
20.
30.
40.

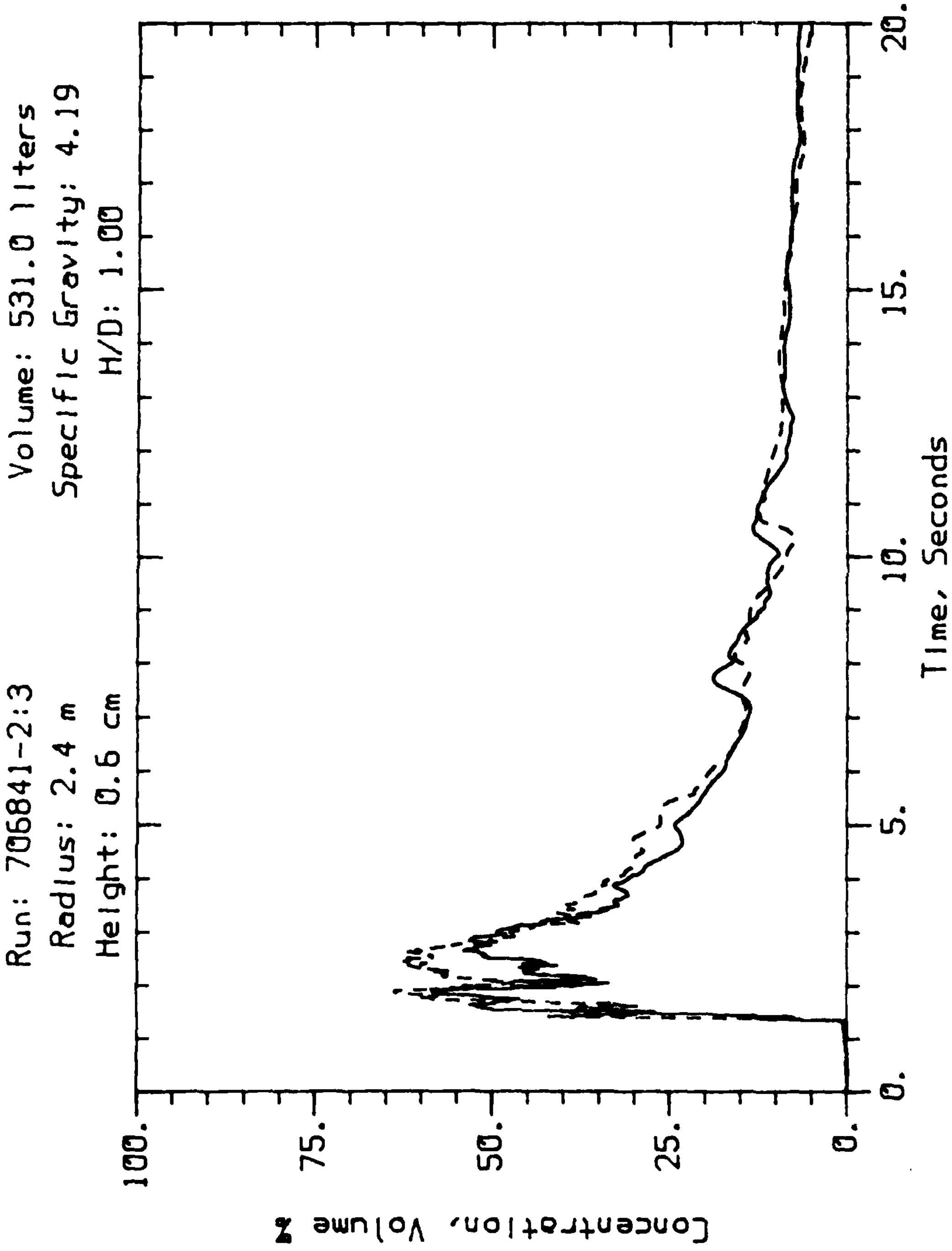


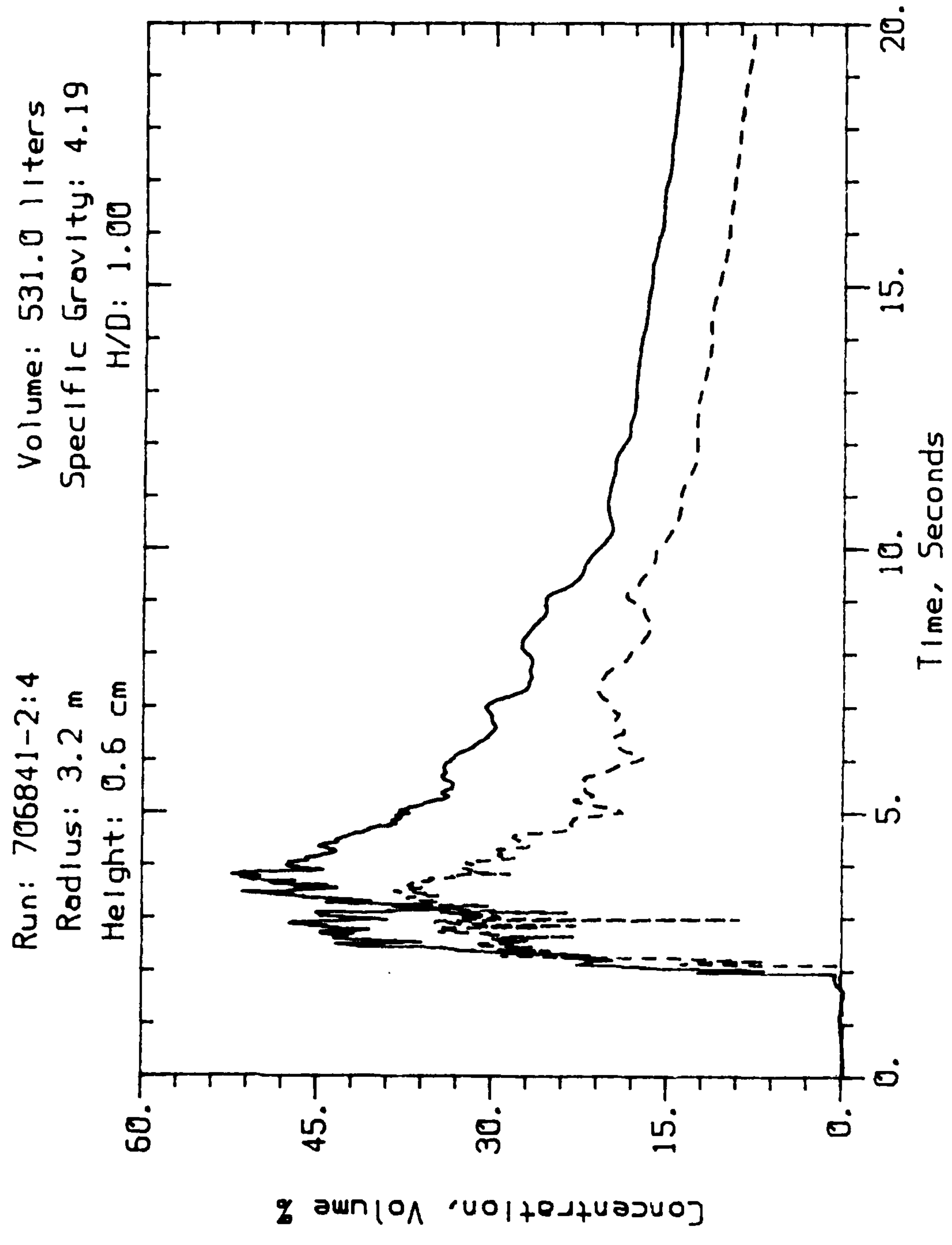
Run: 805831+3:7
Radius: 5.5 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
10.
20.
30.
40.



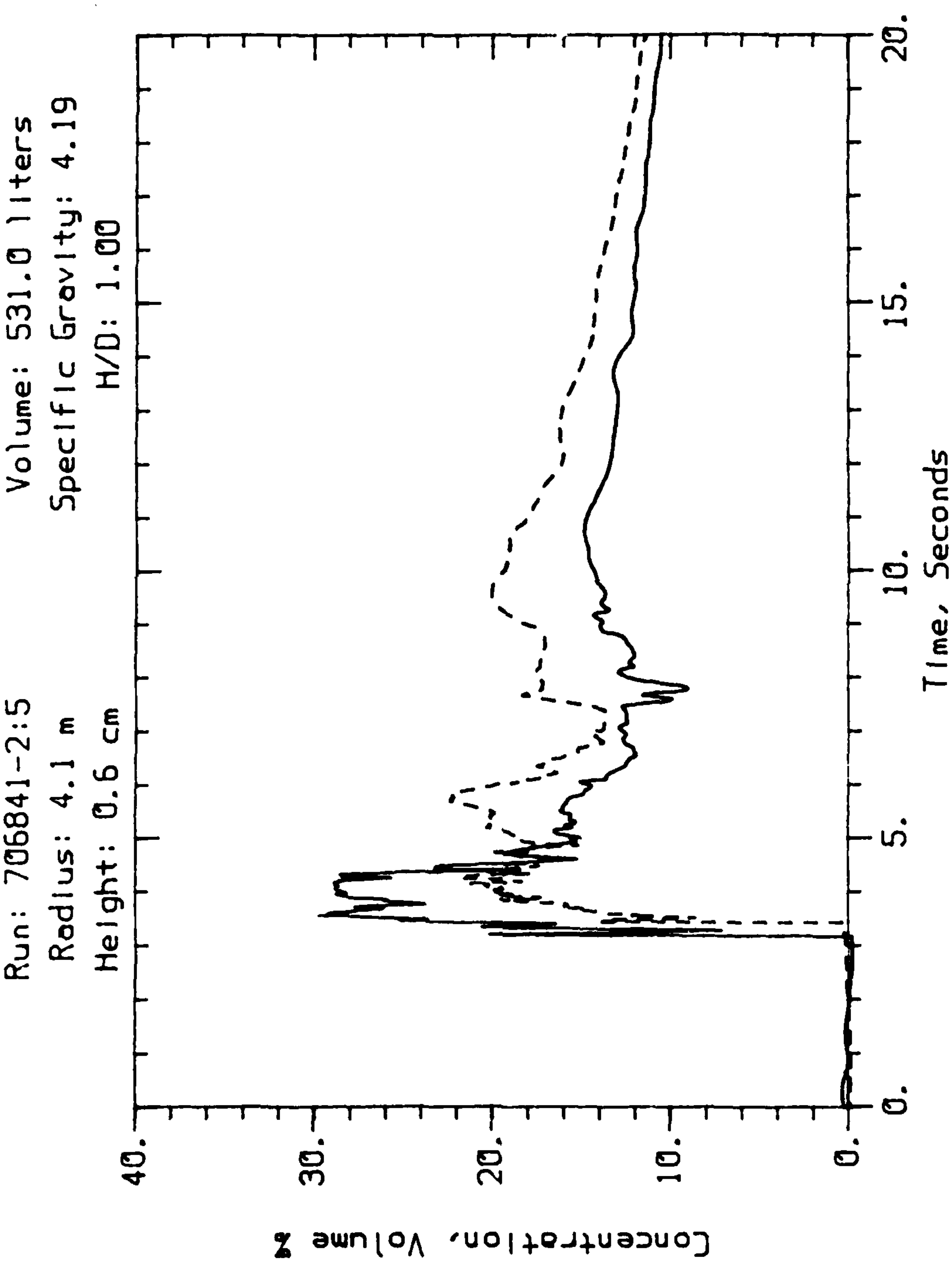
Run: 805831+3:8
Radius: 6.3 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 4.19
H/D: 1.00
Time, Seconds
Concentration, Volume %
0.
10.
20.
30.
40.
0.0
1.0
2.0
3.0
4.0

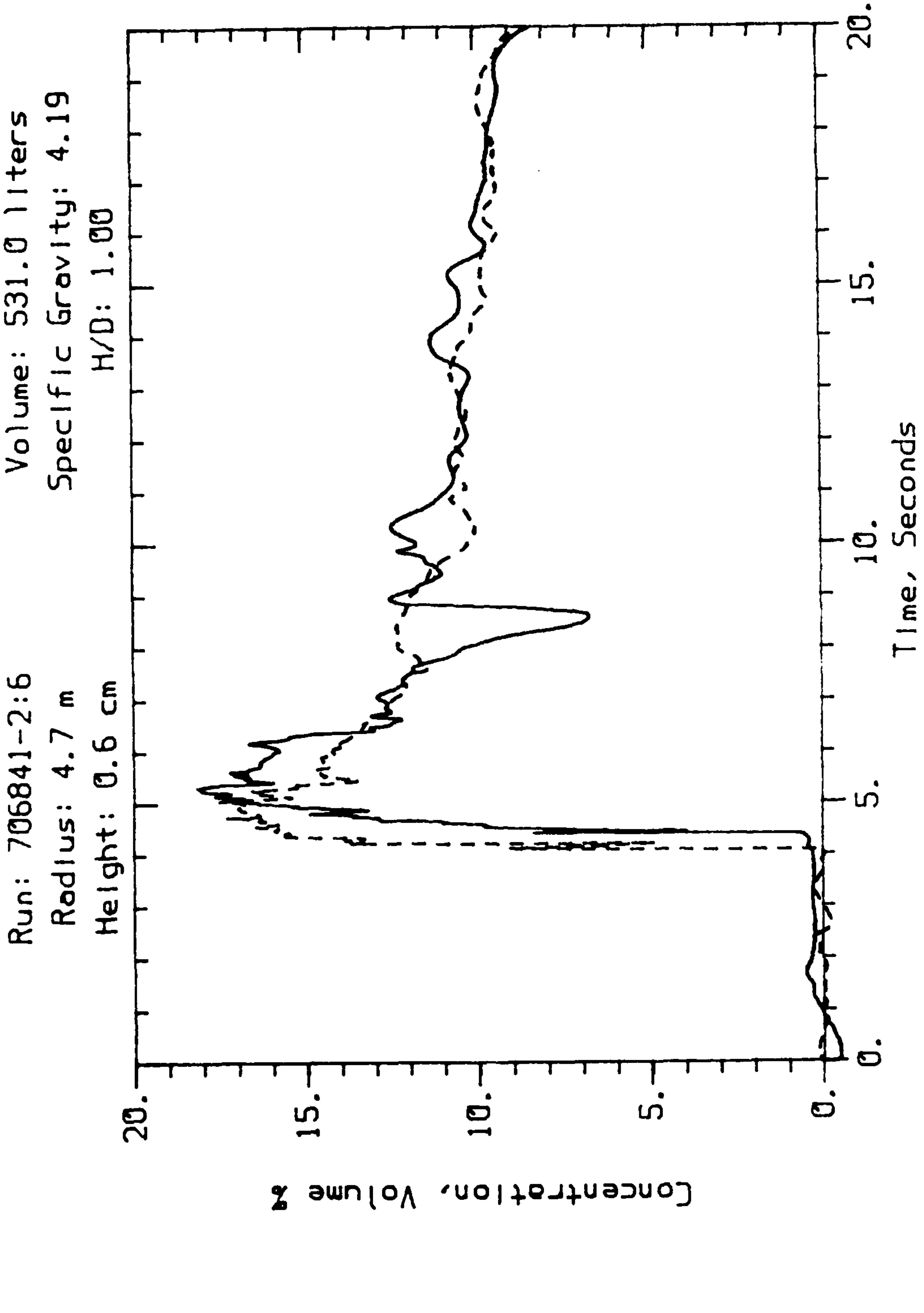

Run: 706841-2:2
Radius: 1.6 m
Height: 0.6 cm
Volume: 531.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
100.
75.
50.
25.
0.
0.
5.
10.
15.
20.
Time, Seconds

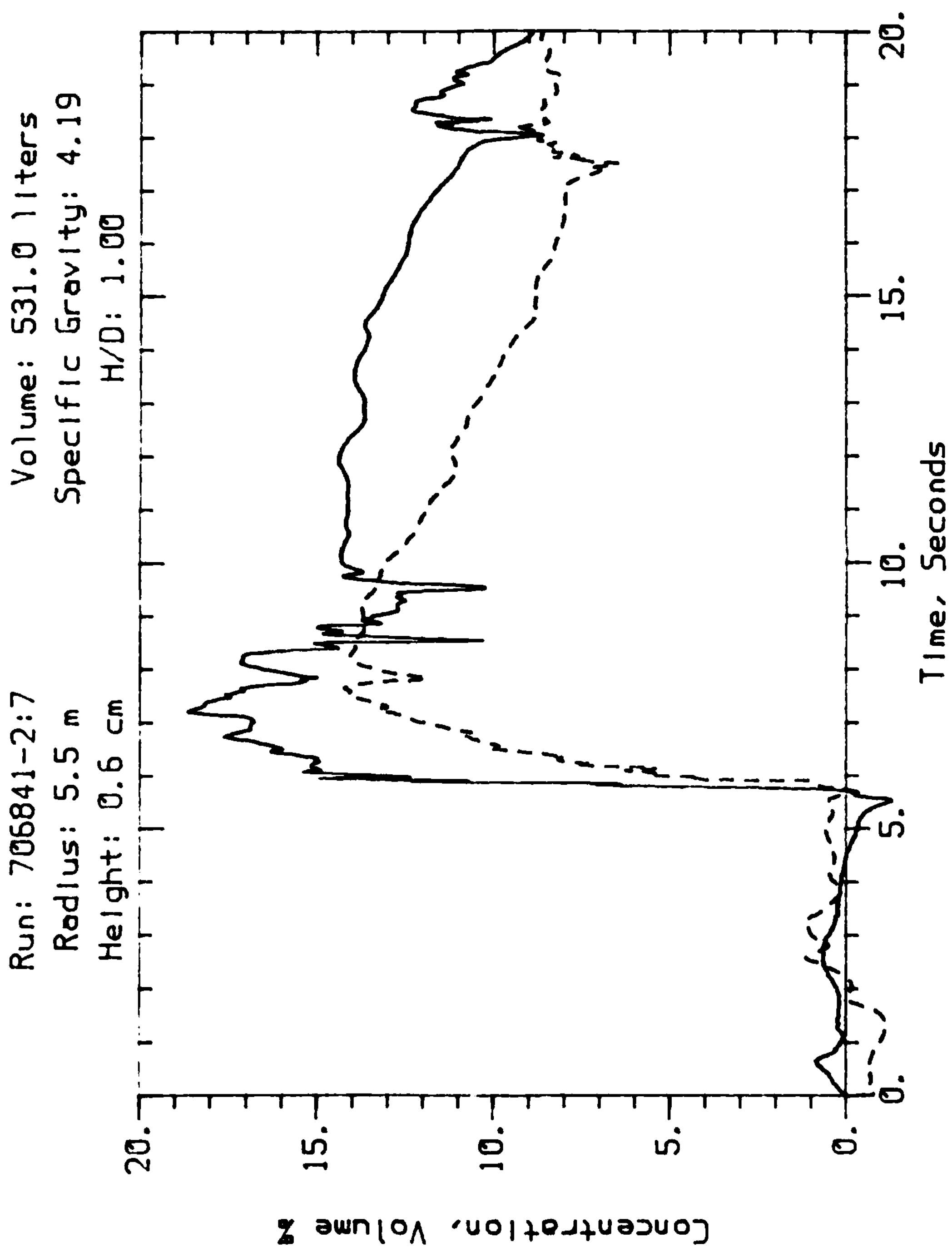

Run: 706841-2:3
Radius: 2.4 m
Height: 0.6 cm
Volume: 531.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
100.
75.
50.
25.
0.
0.
5.
10.
15.
20.
Time, Seconds

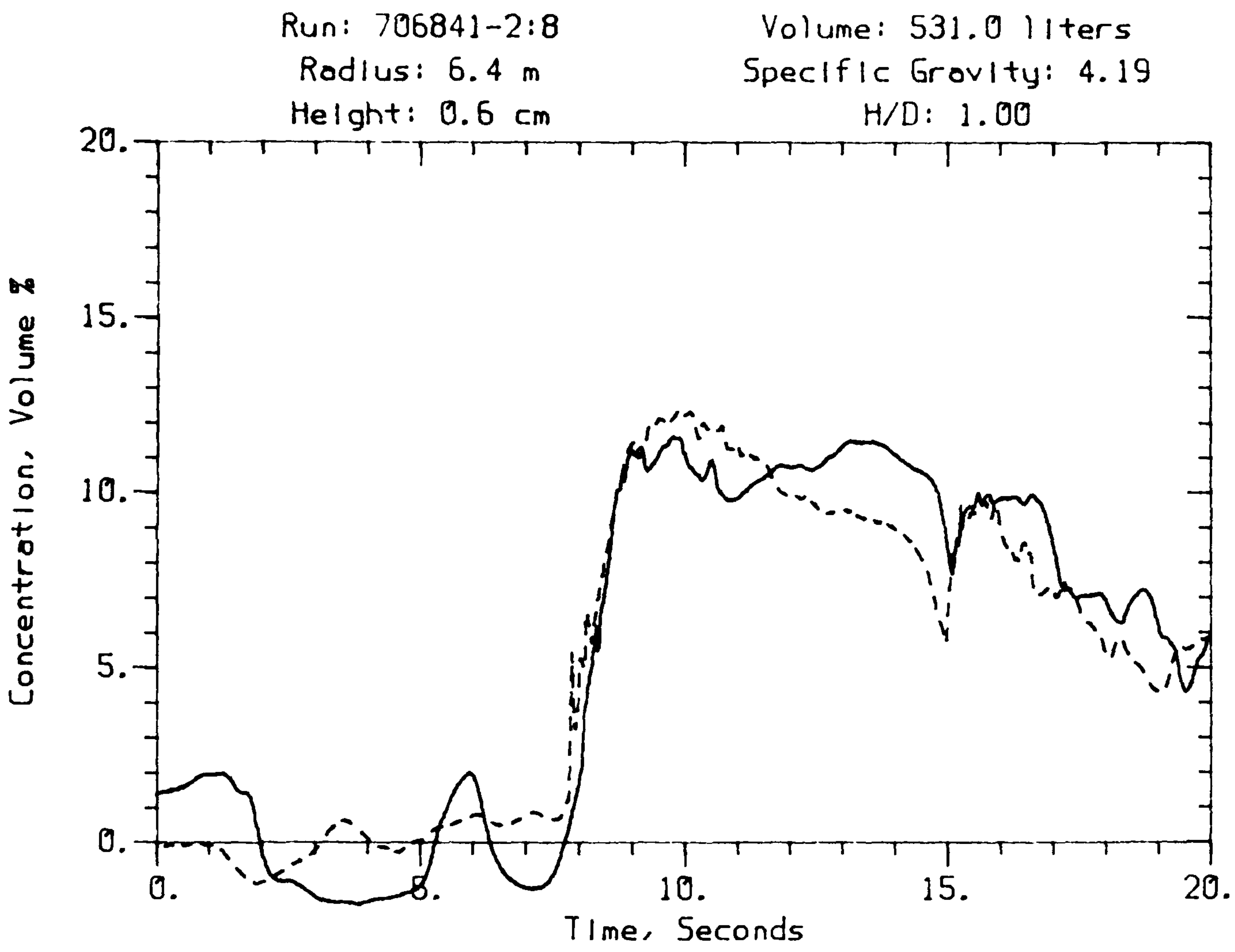


Run: 706841-2:4
Radius: 3.2 m
Height: 0.6 cm
Volume: 531.0 liters
Specific Gravity: 4.19
H/D: 1.00
60.
45.
30.
15.
0.
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

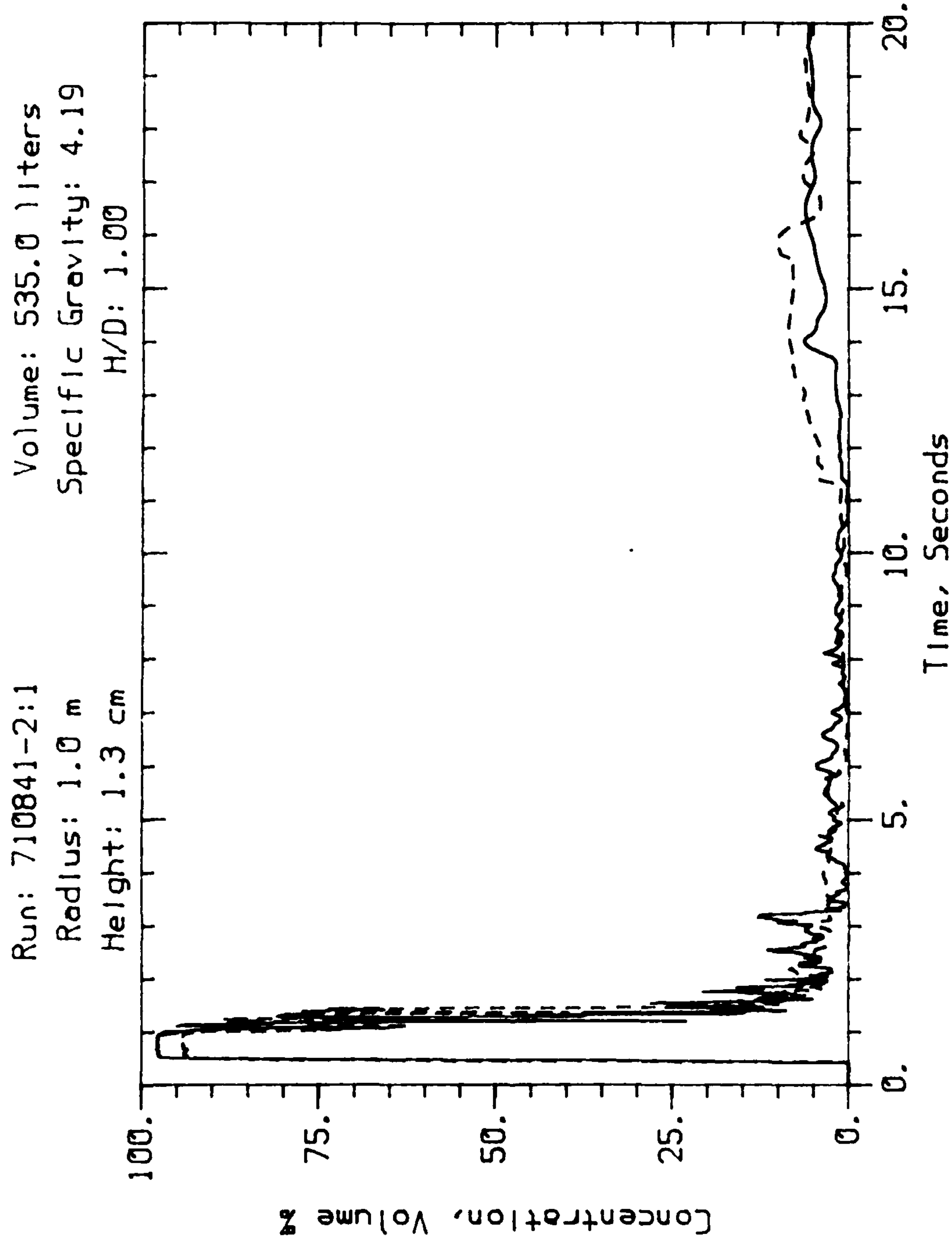

Run: 706841-2:5
Radius: 4.1 m
Height: 0.6 cm
Volume: 531.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
10.
20.
30.
40.
0.
5.
10.
15.
20.

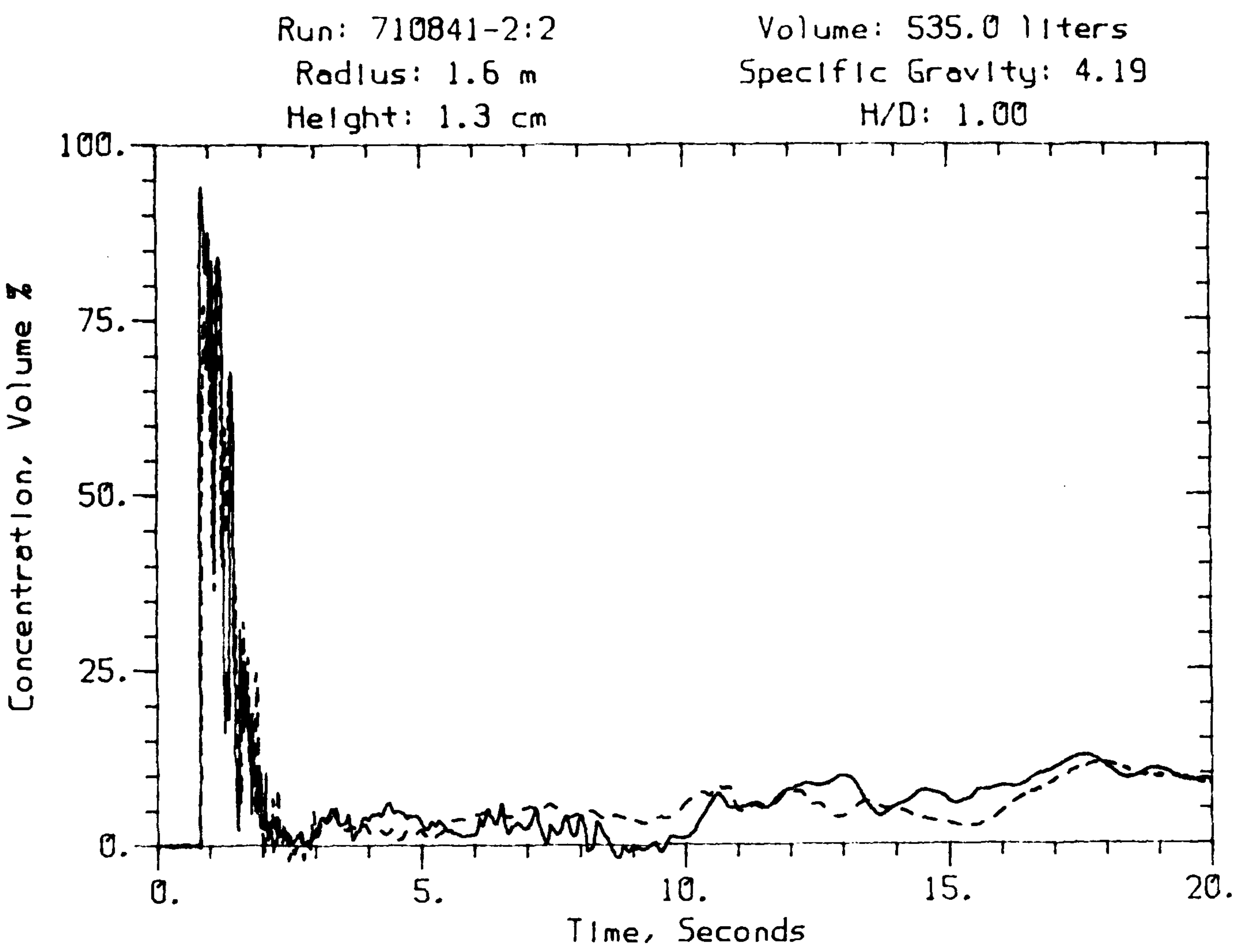

Run: 706841-2:6
Radius: 4.7 m
Height: 0.6 cm
Volume: 531.0 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
Concentration, Volume %

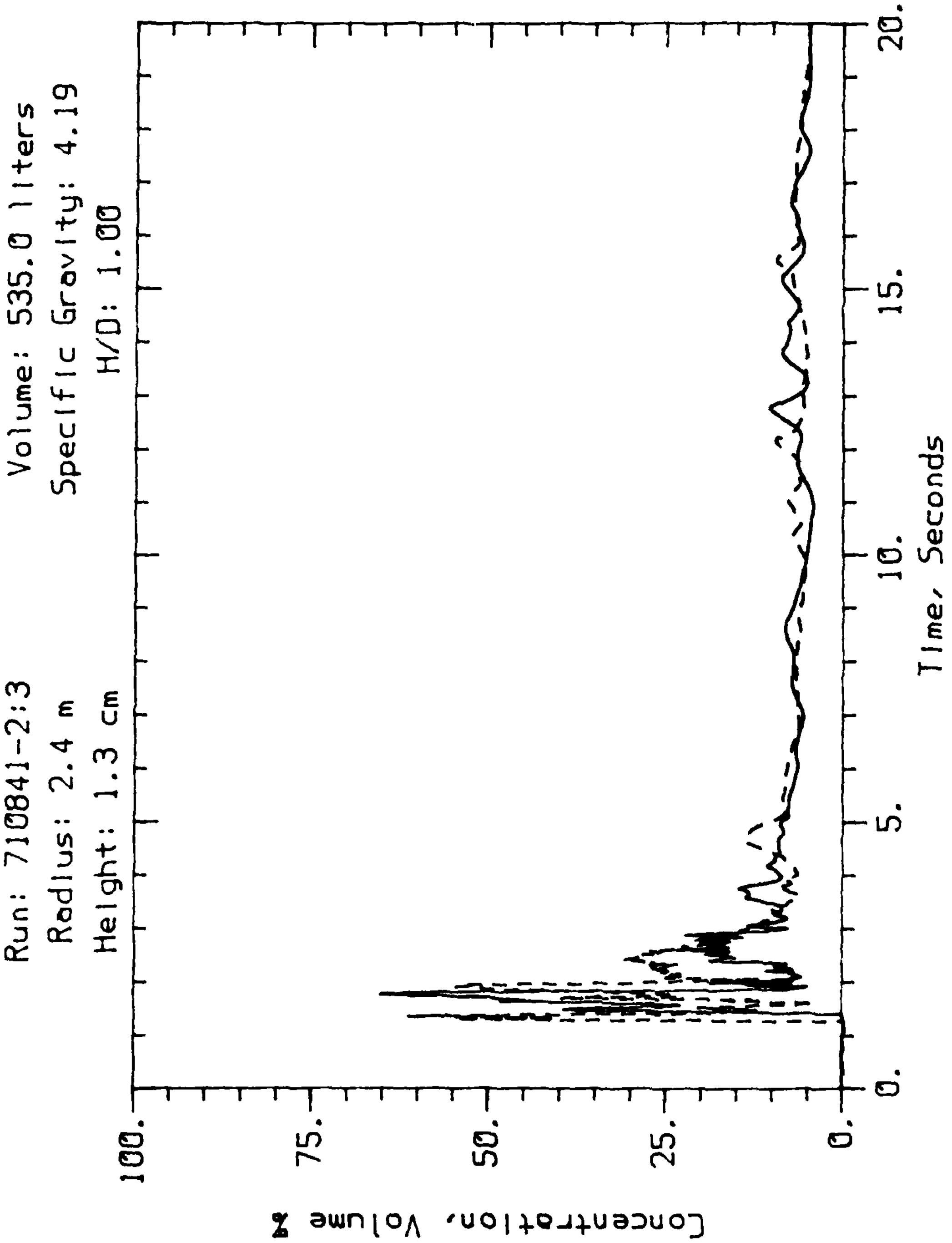

Run: 706841-2:7
Radius: 5.5 m
Height: 0.6 cm
Volume: 531.0 liters
Specific Gravity: 4.19
H/D: 1.00
Time, Seconds
Concentration, Volume %
0.
5.
10.
15.
20.

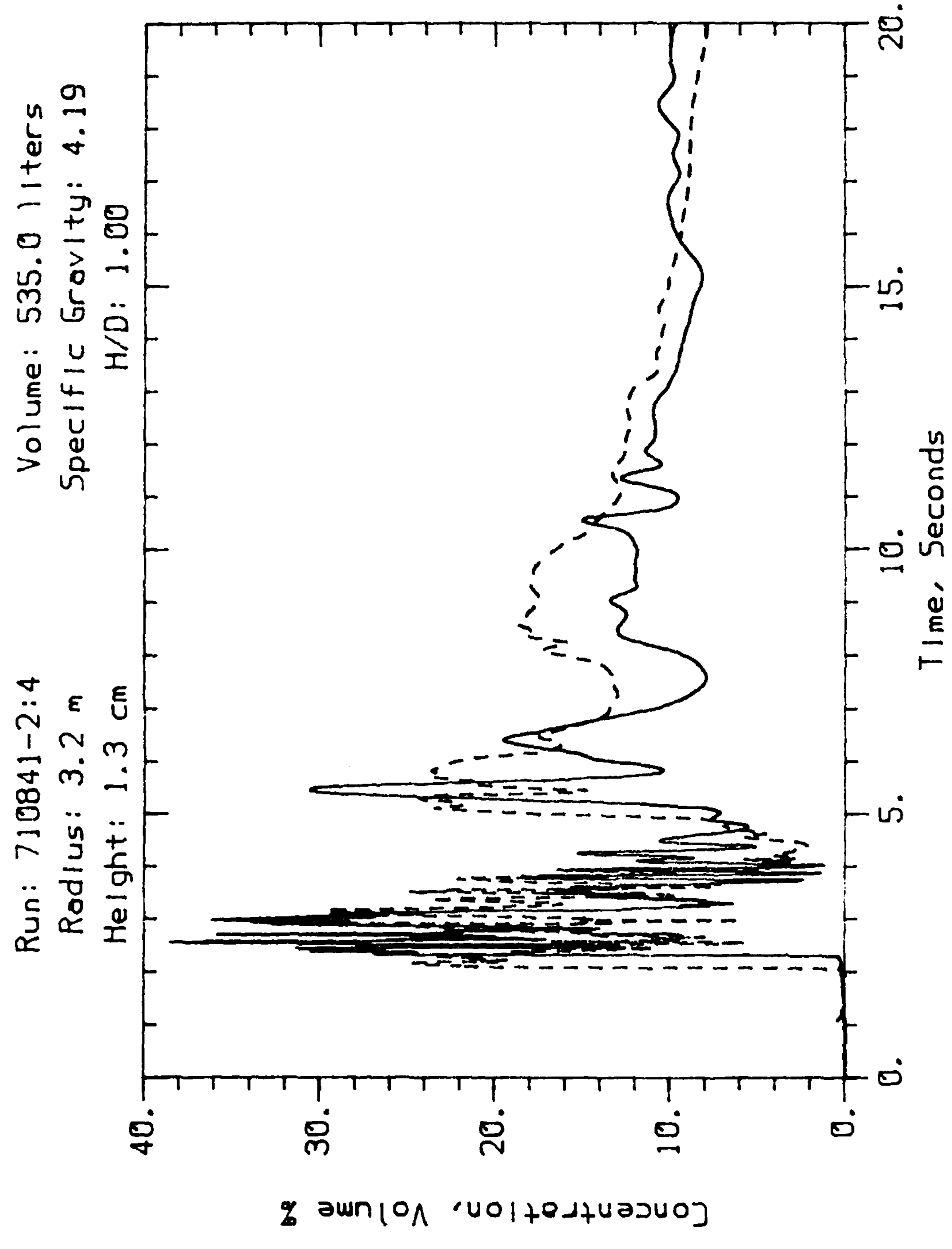


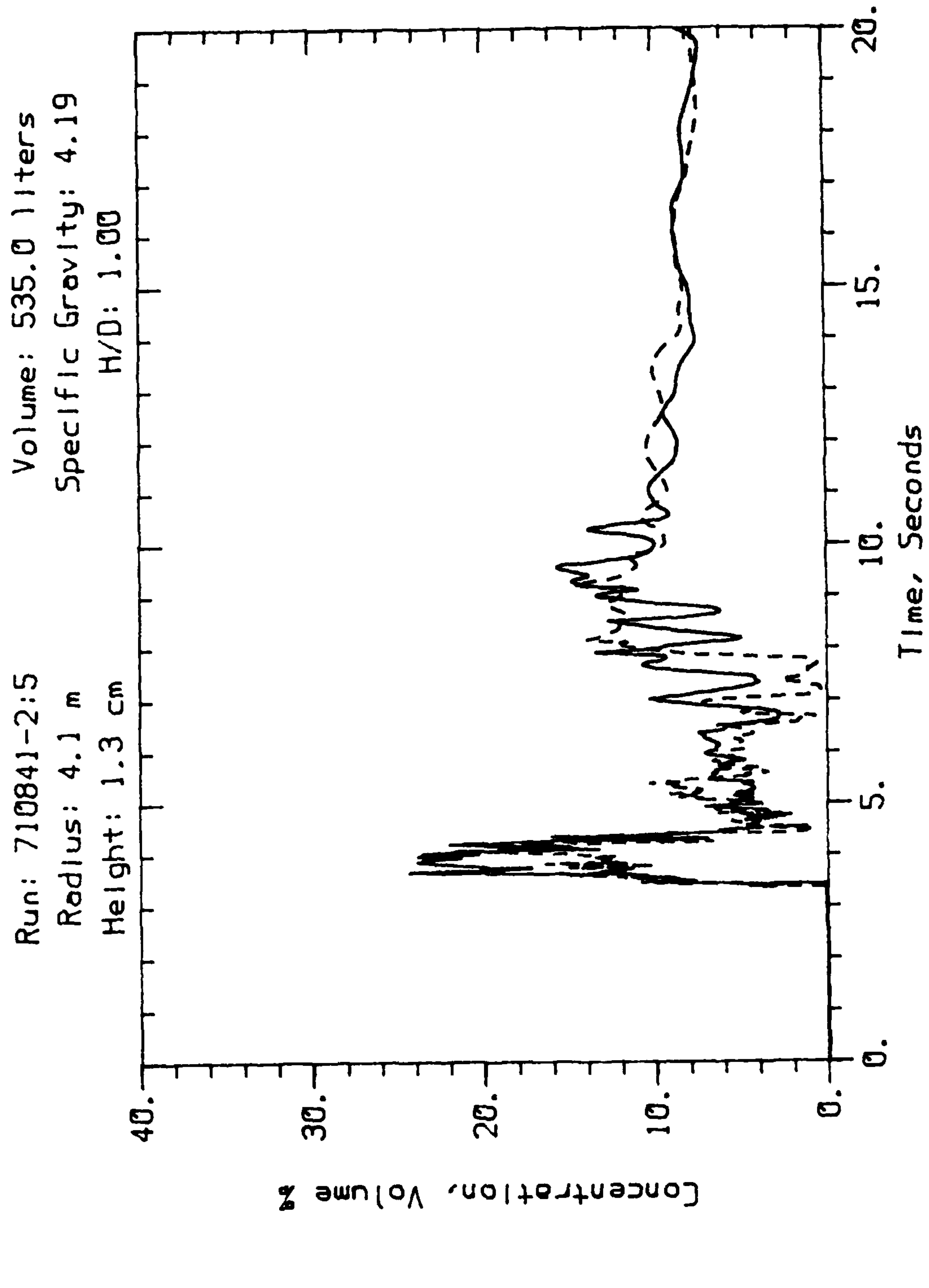
Run: 706841-2:8
Radius: 6.4 m
Height: 0.6 cm
Volume: 531.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
20.
15.
10.
5.
0.
Time, Seconds
0.
5.
10.
15.
20.

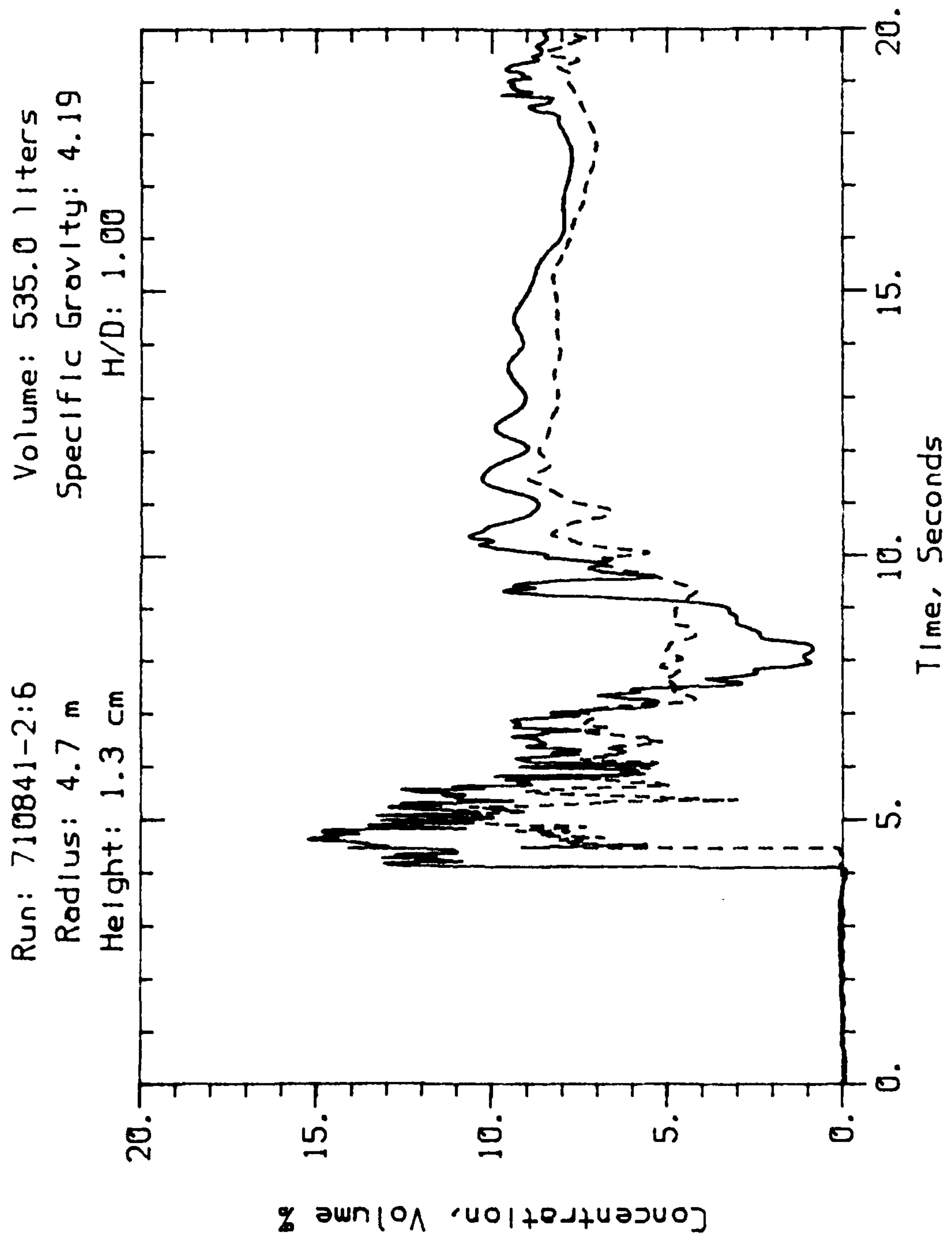

Run: 710841-2:1
Radius: 1.0 m
Height: 1.3 cm
Volume: 535.0 liters
Specific Gravity: 4.19
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.
25.
50.
75.
100.
Concentration, Volume %

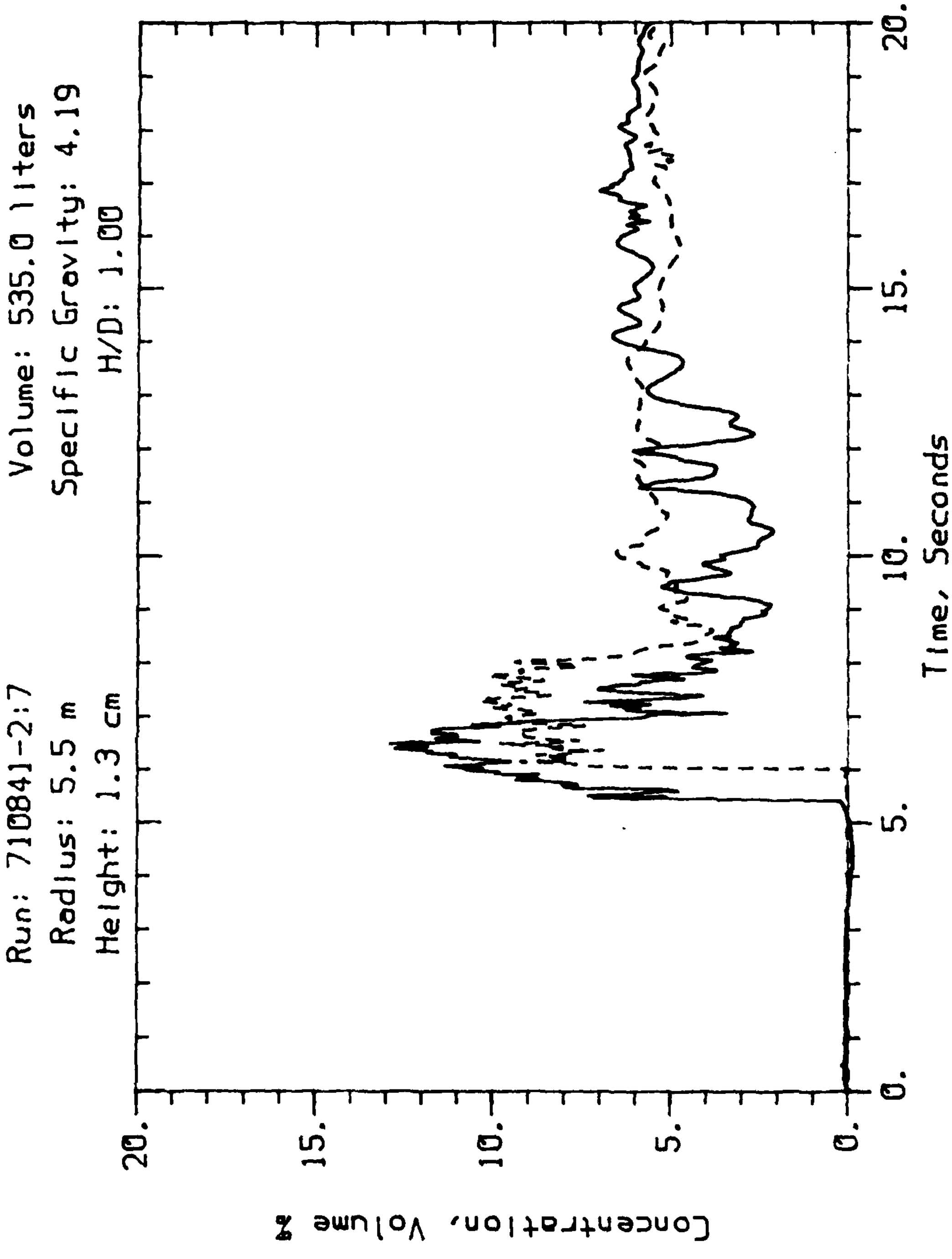

Run: 710841-2:2
Radius: 1.6 m
Height: 1.3 cm
Volume: 535.0 liters
Specific Gravity: 4.19
H/D: 1.00
100.
75.
50.
25.
0.
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

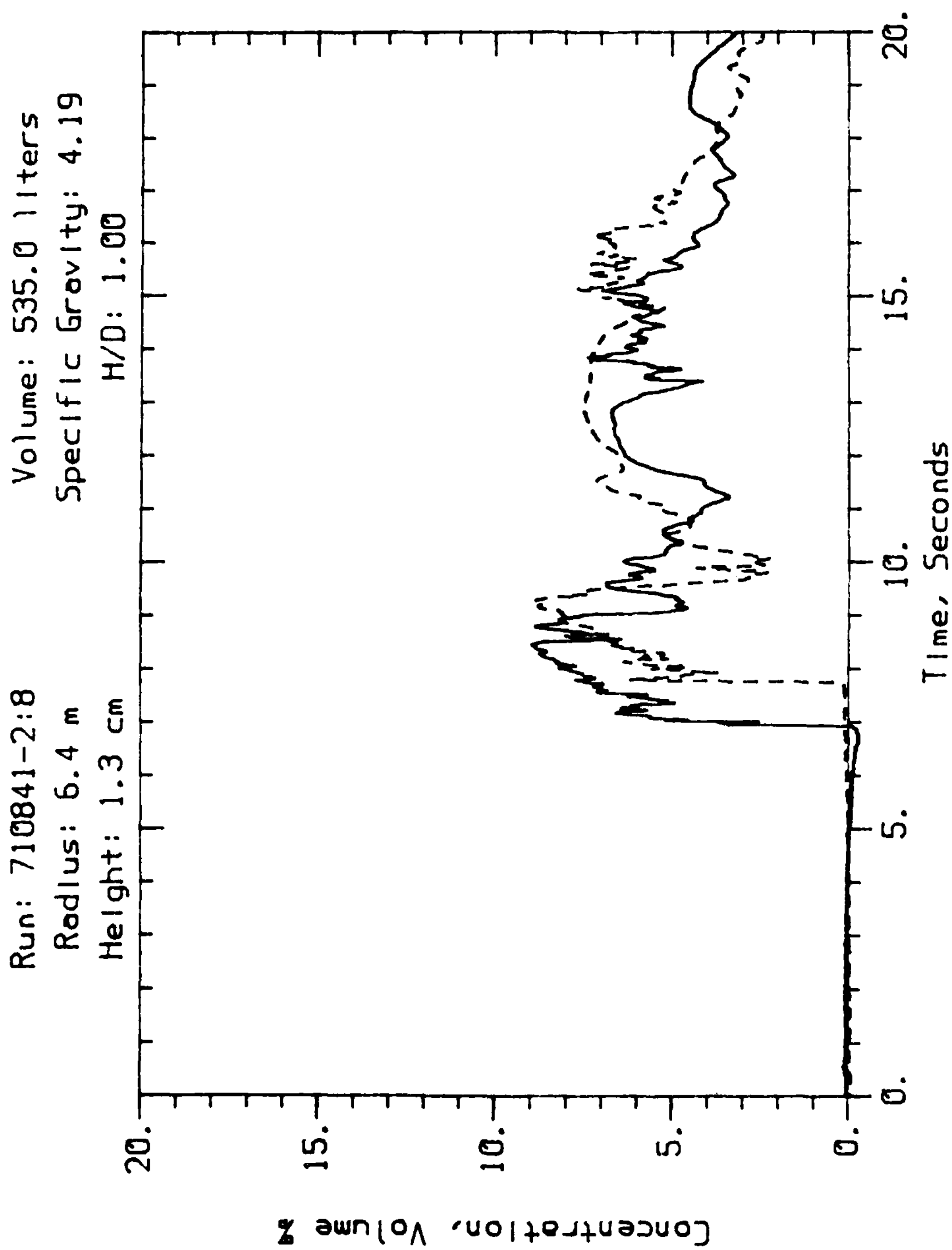

Run: 710841-2:3
Radius: 2.4 m
Height: 1.3 cm
Volume: 535.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
100.
75.
50.
25.
0.
0.
5.
10.
15.
20.
Time, Seconds

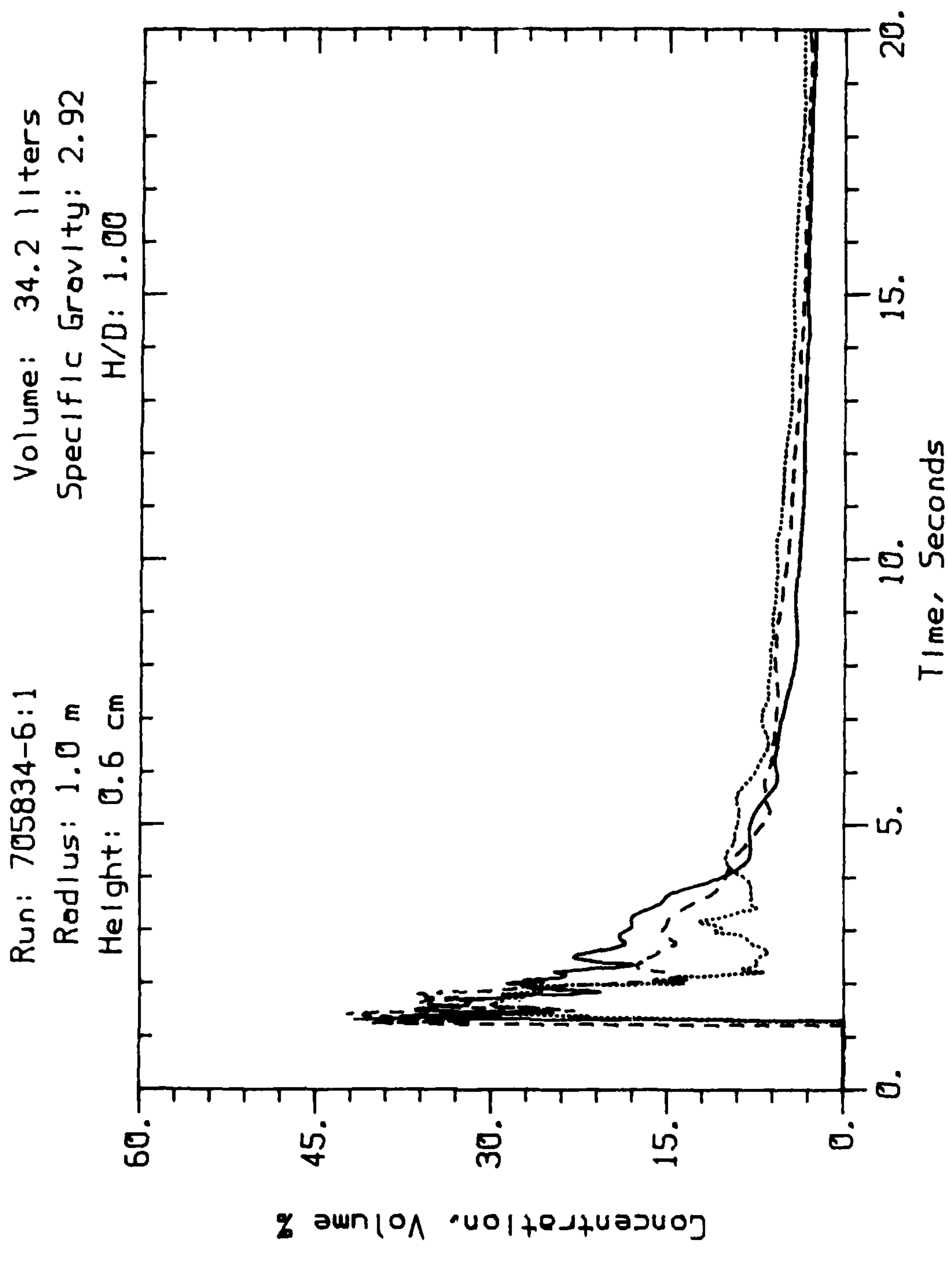

Run: 710841-2:4
Radius: 3.2 m
Height: 1.3 cm
Volume: 535.0 liters
Specific Gravity: 4.19
H/D: 1.00
40.
30.
20.
10.
0.
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds


Run: 710841-2:5
Radius: 4.1 m
Height: 1.3 cm
Volume: 535.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
10.
20.
30.
40.
0.
5.
10.
15.
20.

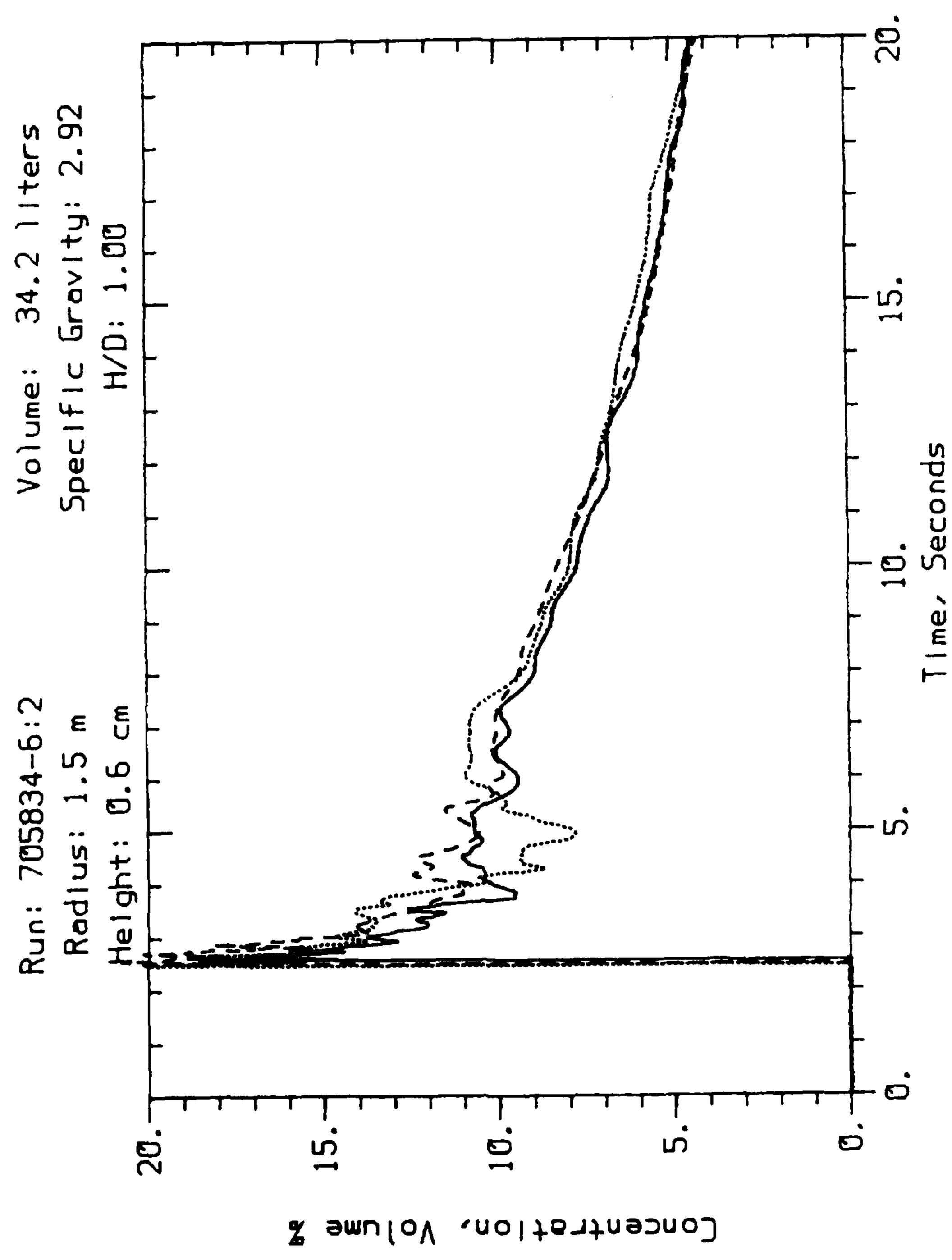

Run: 710841-2:6
Radius: 4.7 m
Height: 1.3 cm
Volume: 535.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

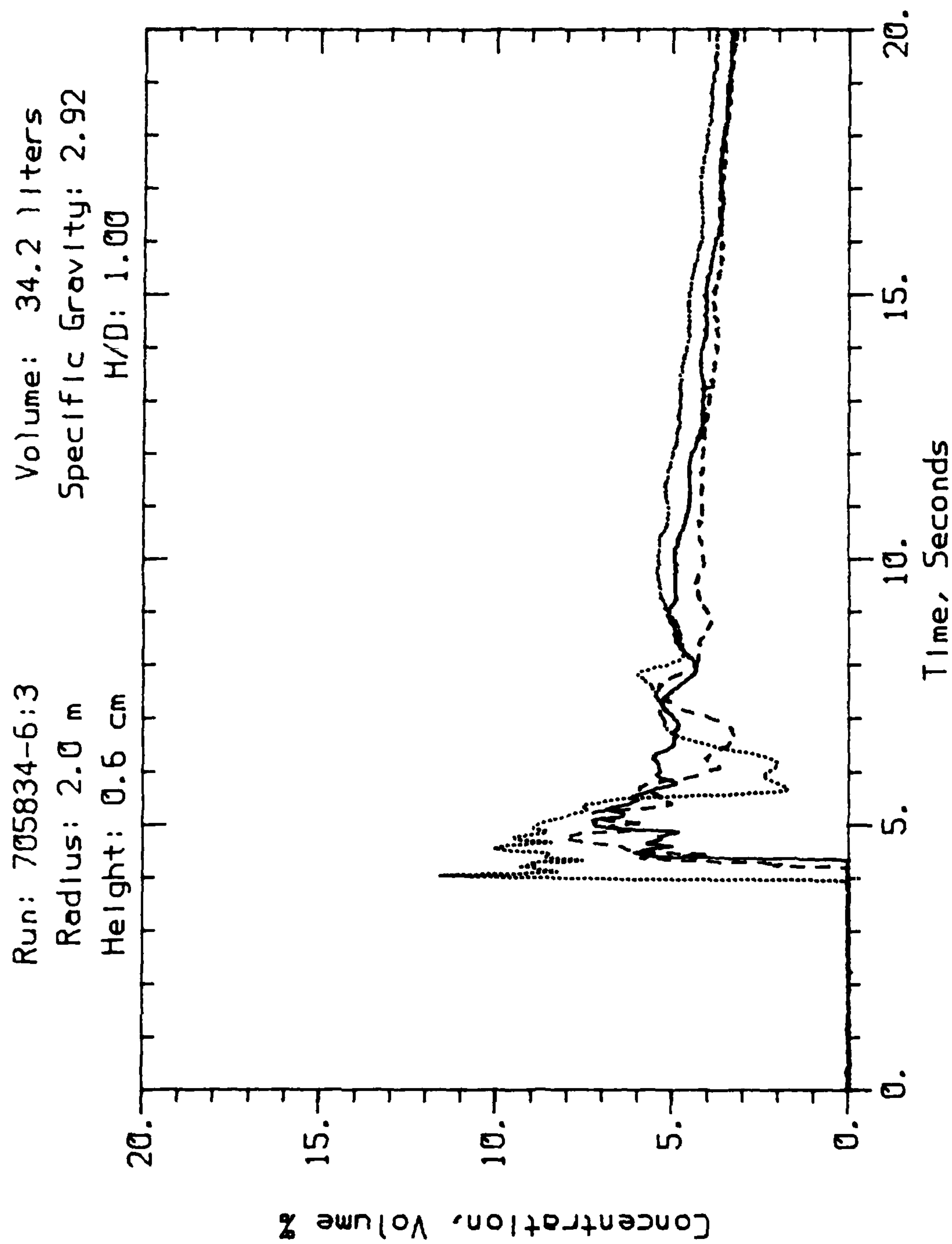

Run: 710841-2:7
Radius: 5.5 m
Height: 1.3 cm
Volume: 535.0 liters
Specific Gravity: 4.19
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

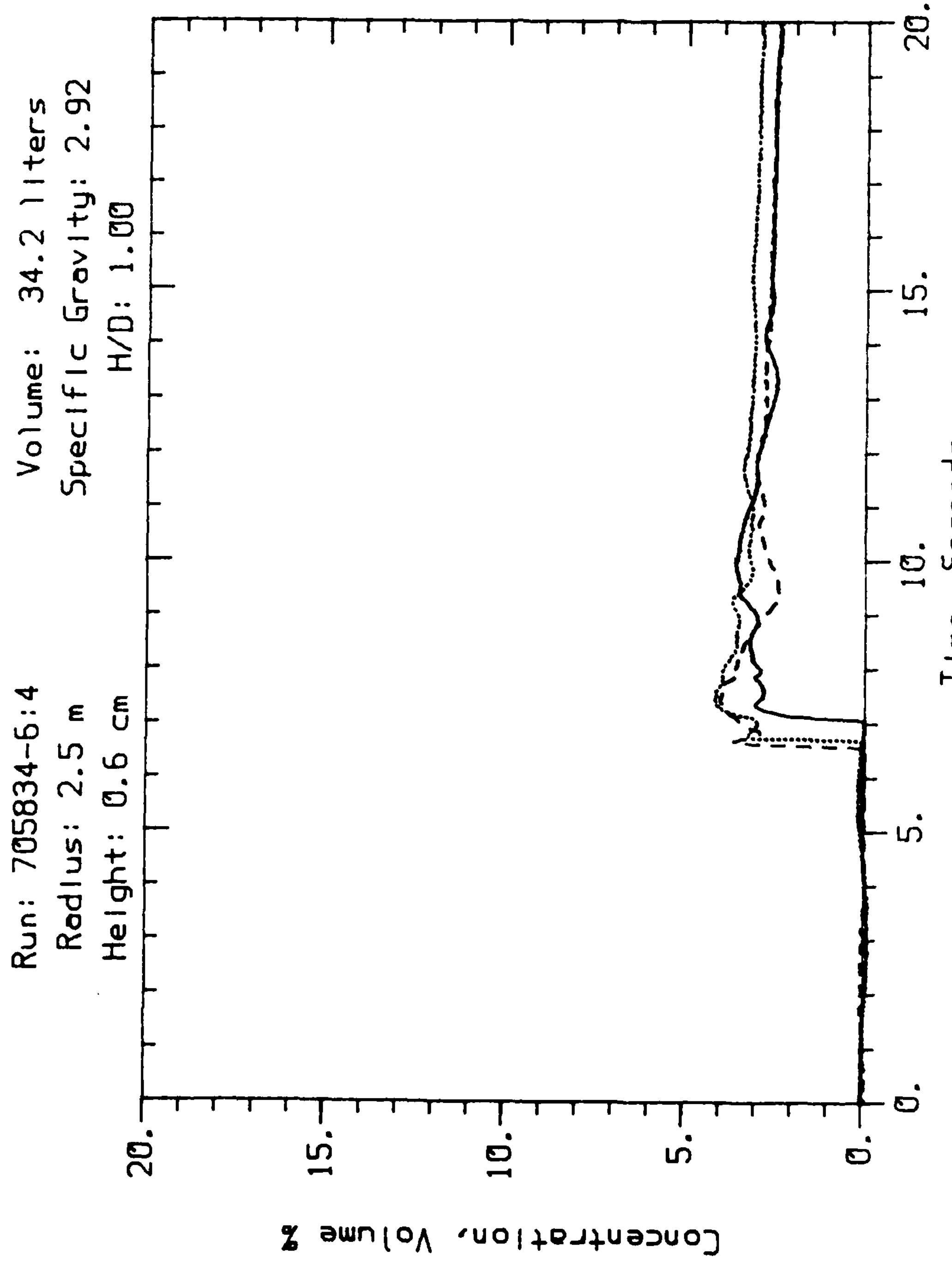

Run: 710841-2:8
Radius: 6.4 m
Height: 1.3 cm
Volume: 535.0 liters
Specific Gravity: 4.19
H/D: 1.00
Time, Seconds
Concentration, Volume %
0.
5.
10.
15.
20.

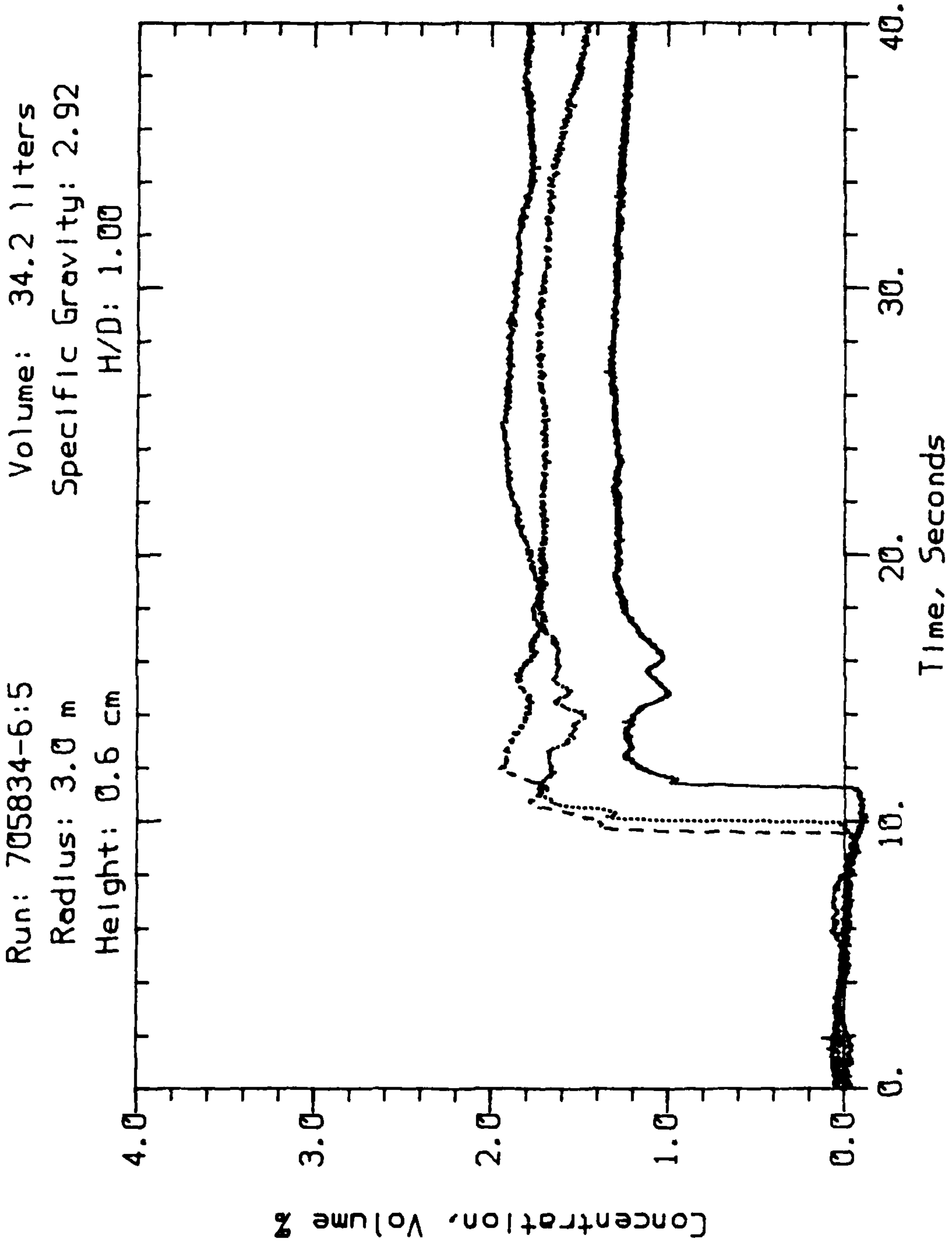

Run: 705834-6:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
0.
15.
30.
45.
60.
Time, Seconds
0.
5.
10.
15.
20.

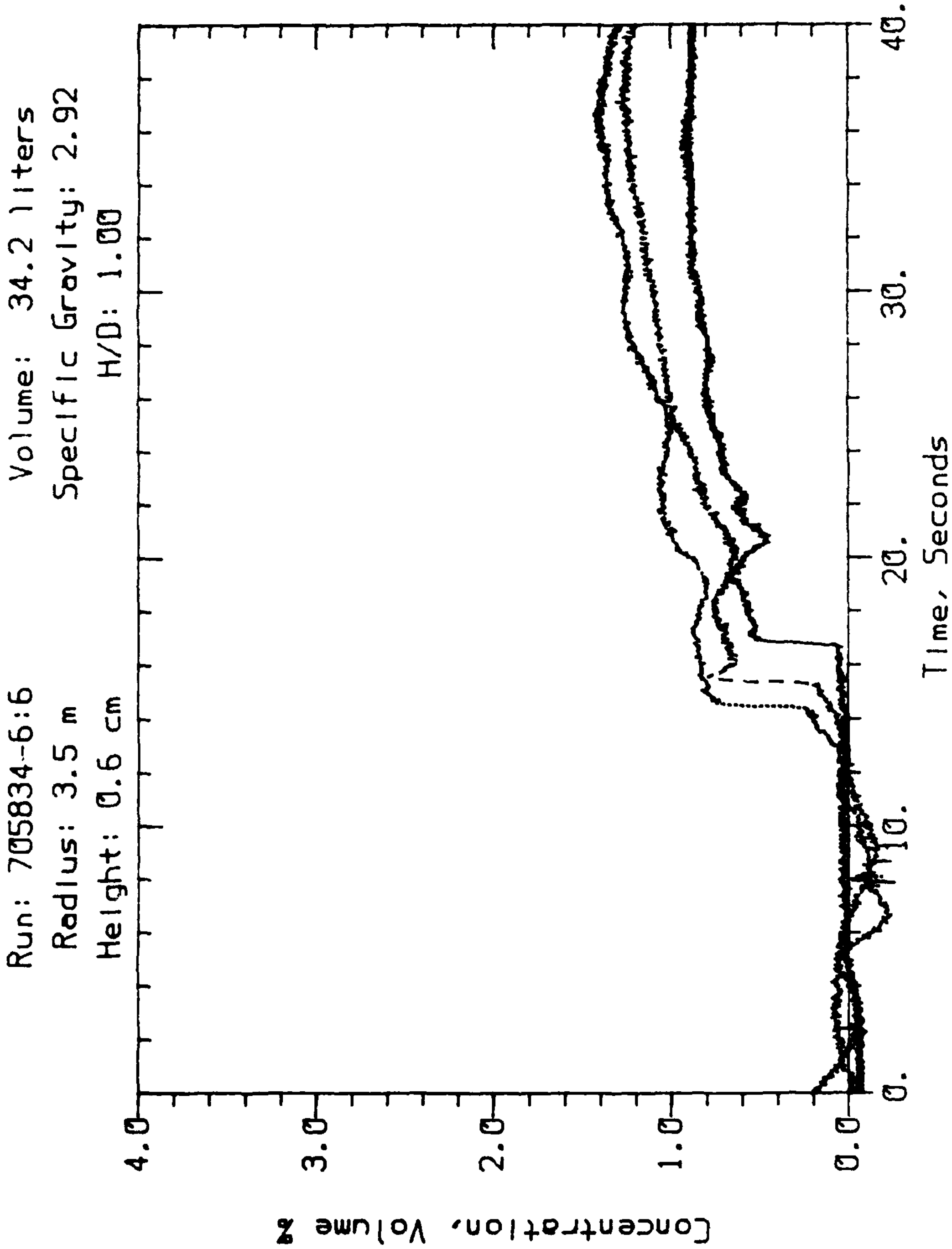
A-128


Run: 705834-6:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
20.
15.
10.
5.
0.
Time, Seconds

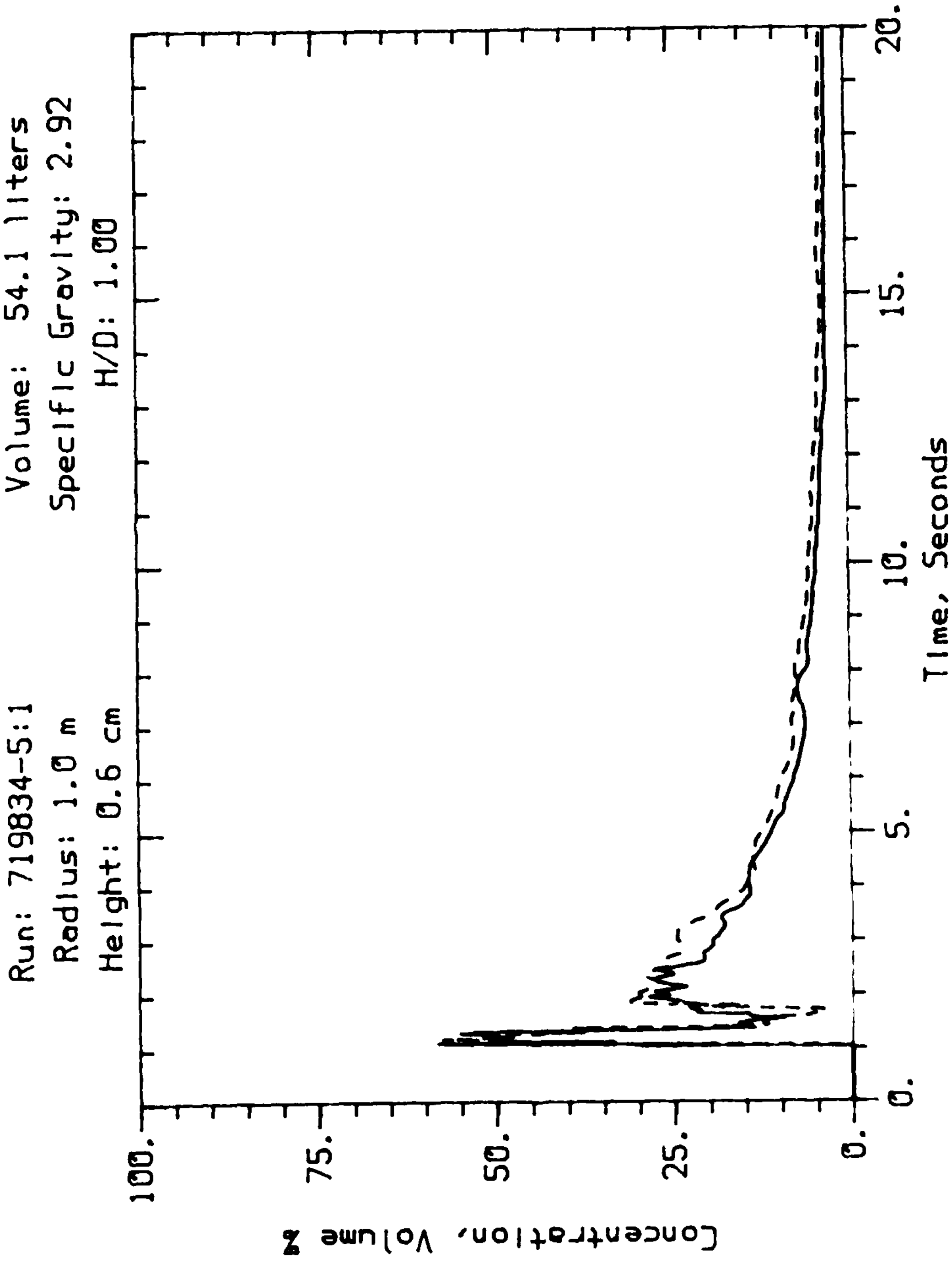

Run: 705834-6:3
Radius: 2.0 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

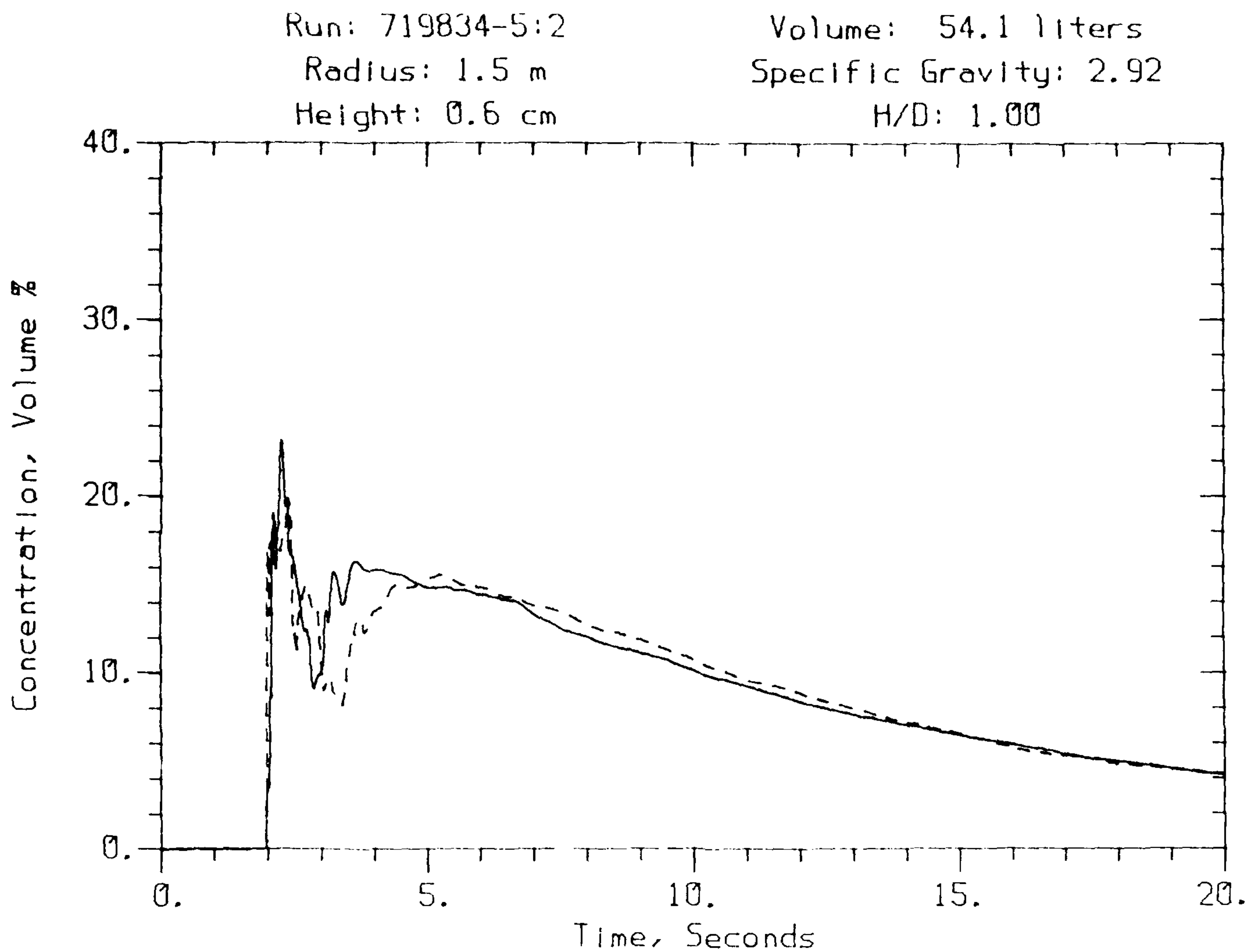

Run: 705834-6:4
Radius: 2.5 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
5.
10.
15.
20.

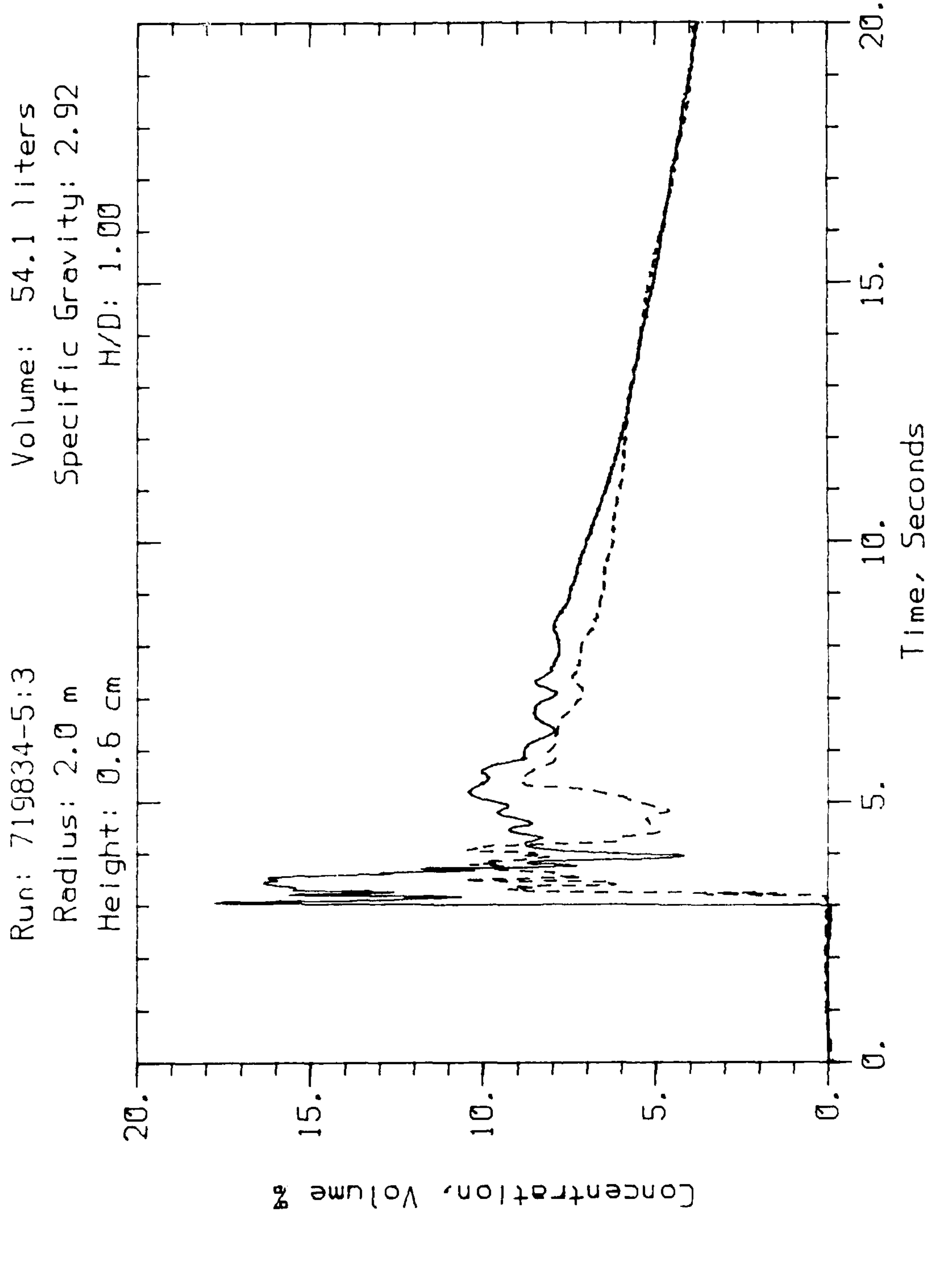

Run: 705834-6:5
Radius: 3.0 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
0.
10.
20.
30.
40.
Time, Seconds



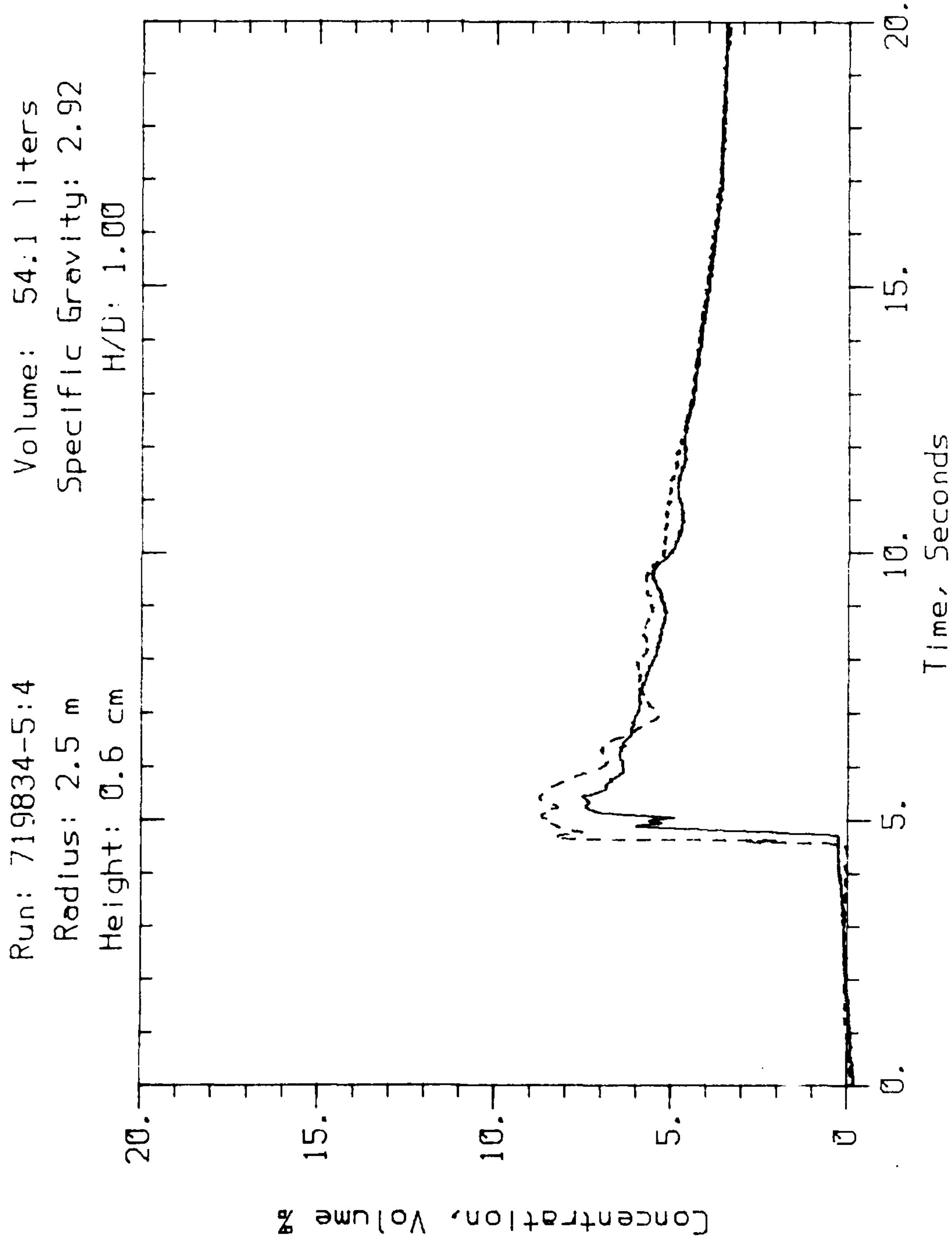
Run: 705834-6:6
Radius: 3.5 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
0.
10.
20.
30.
40.
Time, Seconds

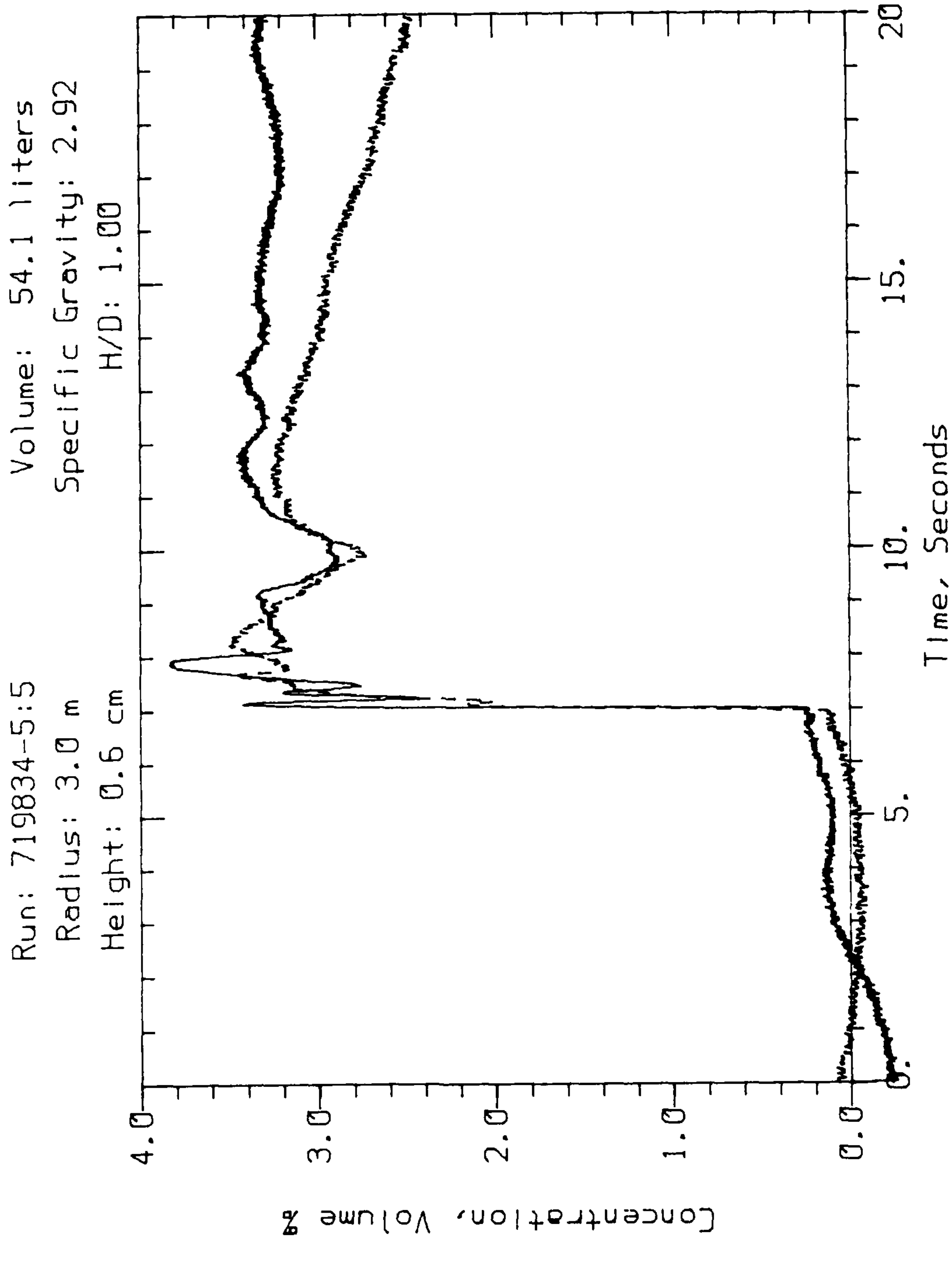

Run: 719834-5:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 2.92
H/D: 1.00
Time, Seconds
Concentration, Volume %
0.
5.
10.
15.
20.
25.
50.
75.
100.

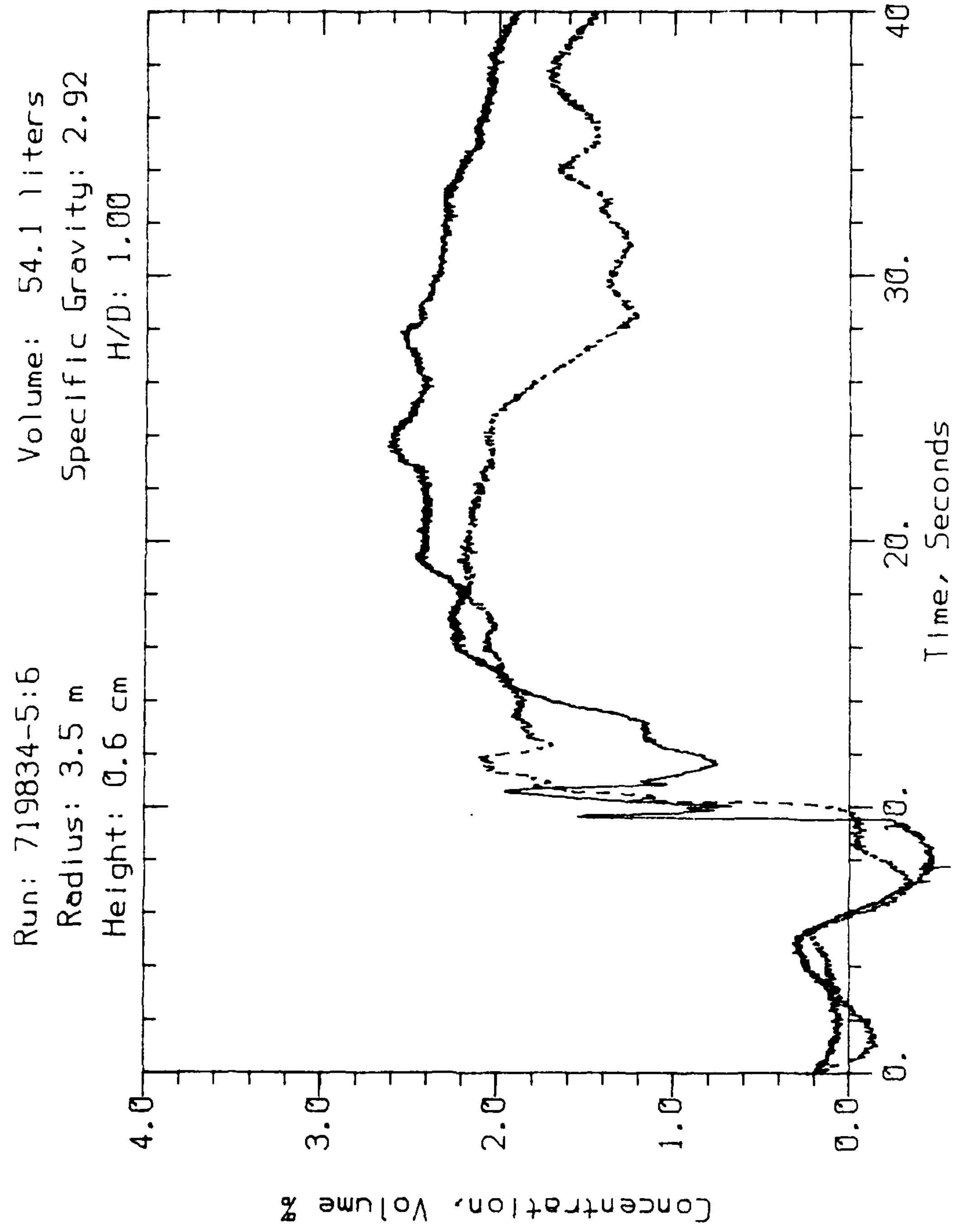

Run: 719834-5:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
40.
30.
20.
10.
0.
0.
5.
10.
15.
20.
Time, Seconds



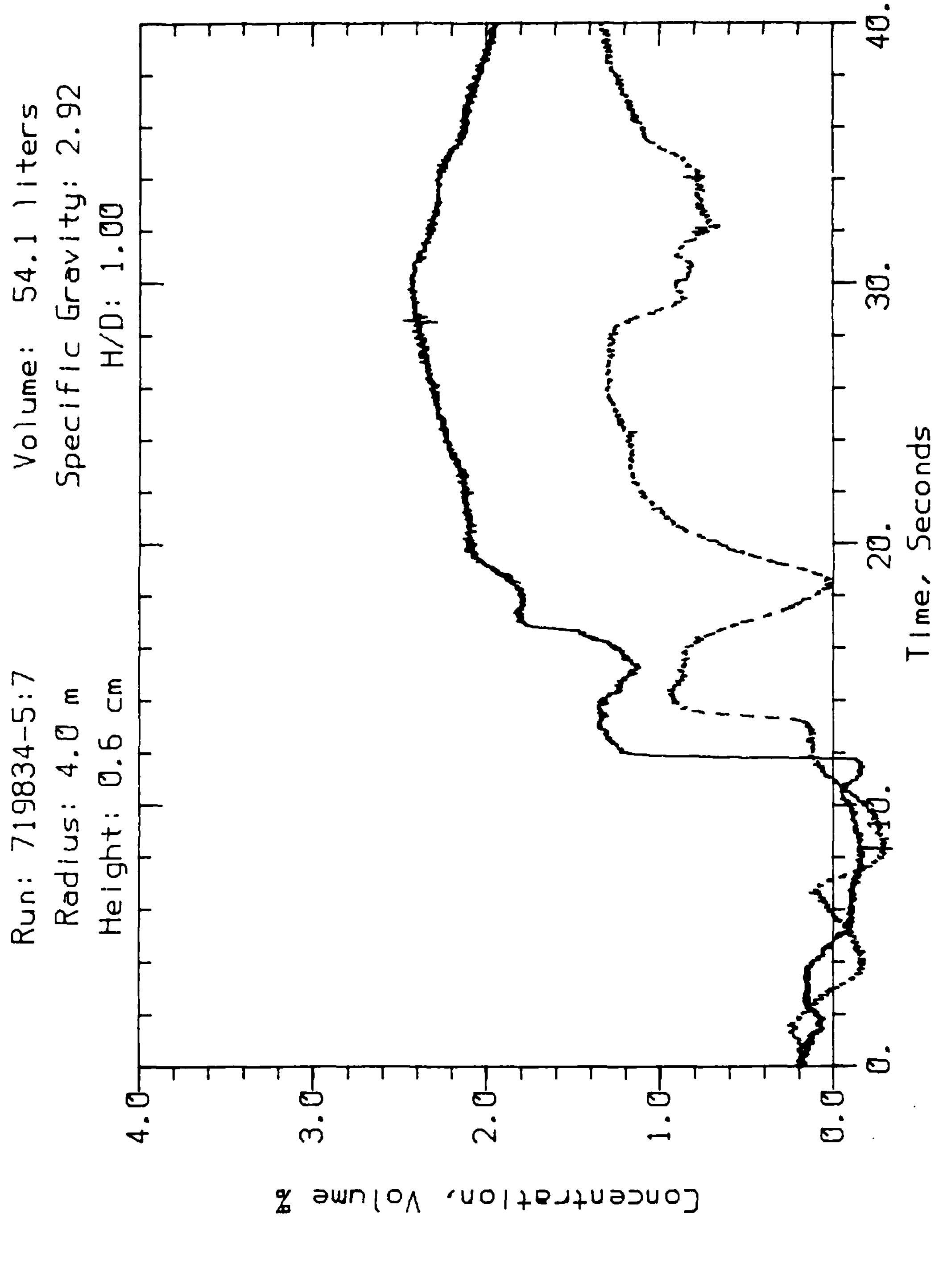
Run: 719834-5:3
Radius: 2.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 2.92
H/D: 1.00
Time, Seconds
Concentration, Volume %
0.
5.
10.
15.
20.


Run: 719834-5:4
Radius: 2.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

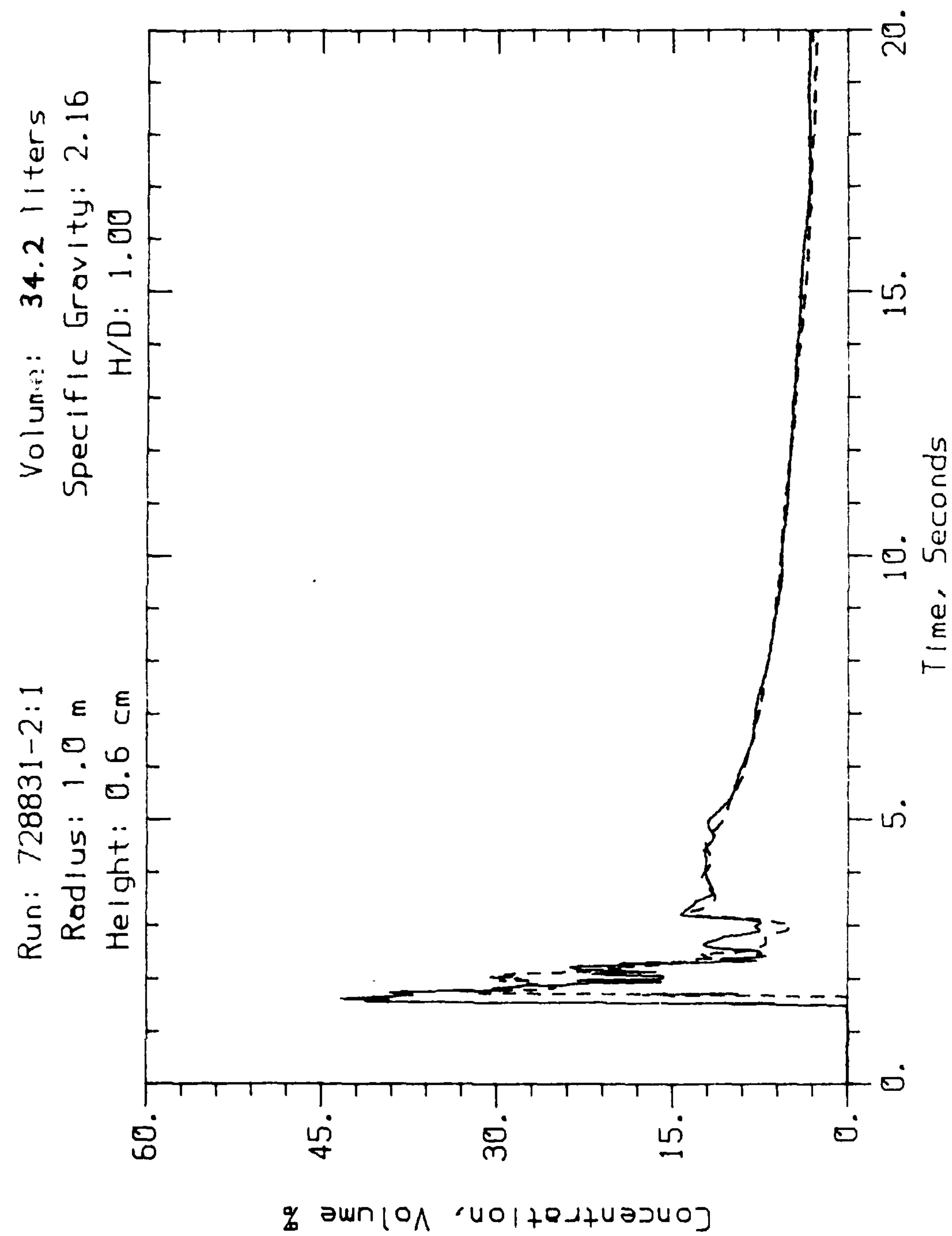

Run: 719834-5:5
Radius: 3.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
4.0
3.0
2.0
1.0
0.0
Time, Seconds
0.
5.
10.
15.
20.

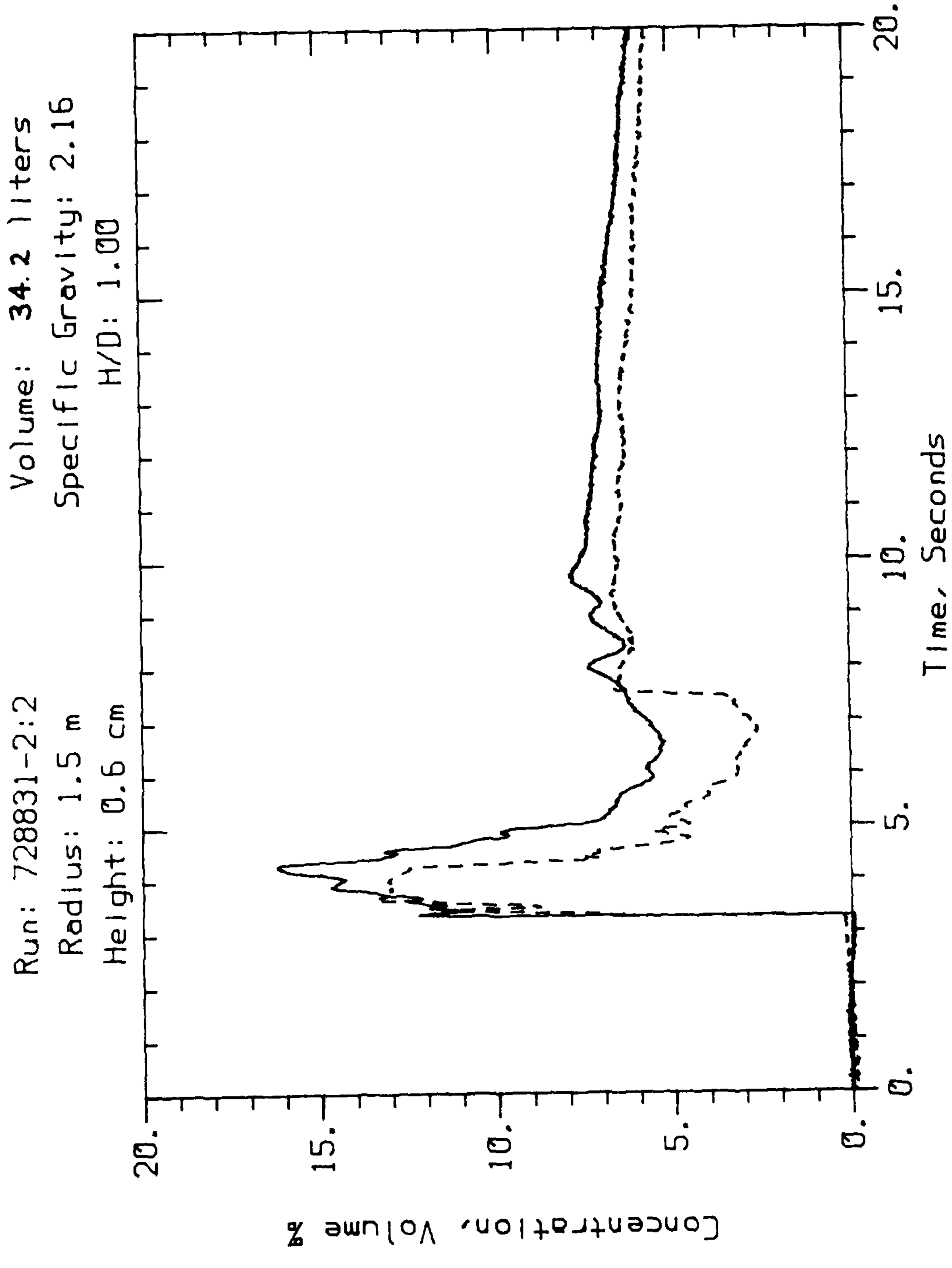


Run: 719834-5:6
Radius: 3.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
10.
20.
30.
40.

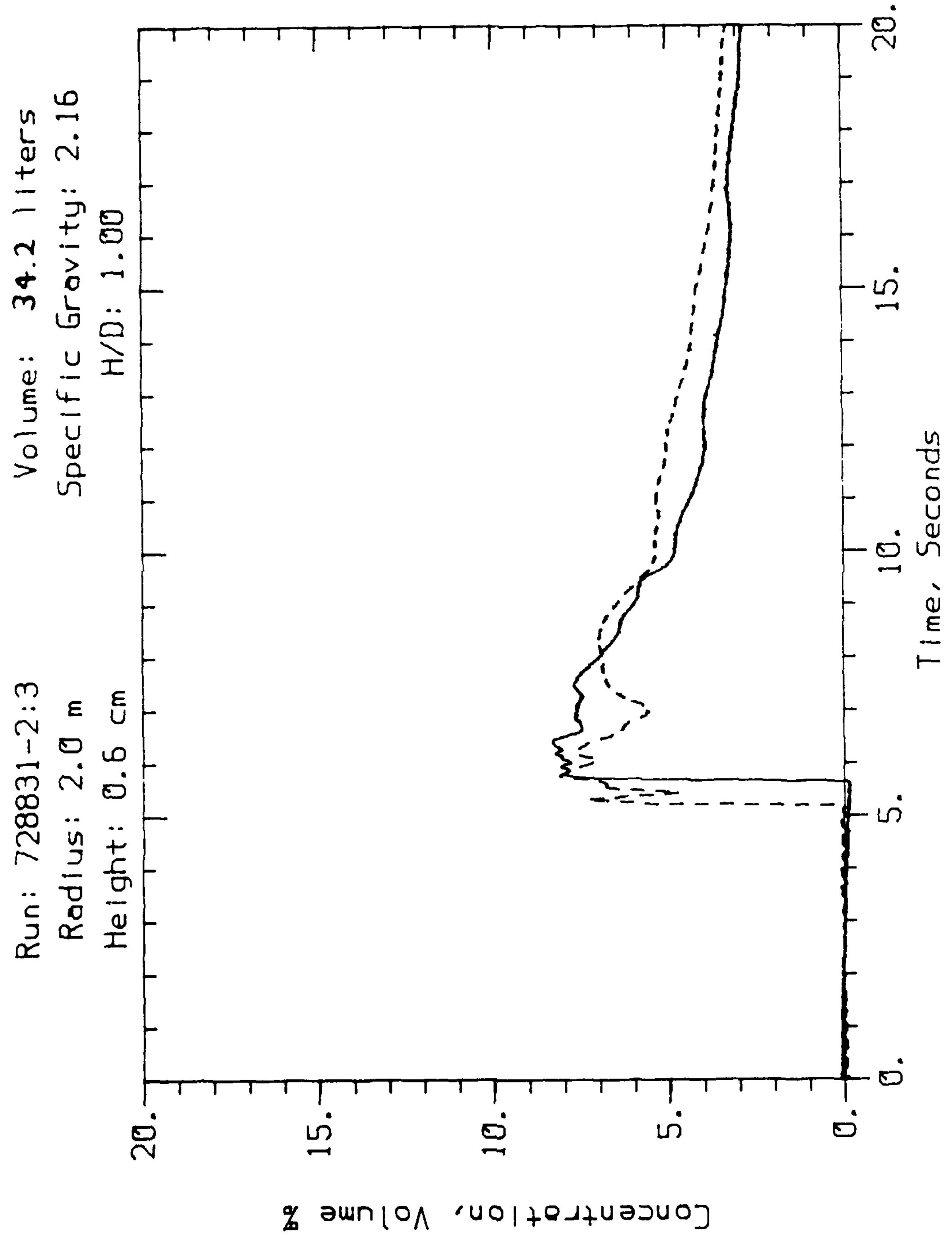


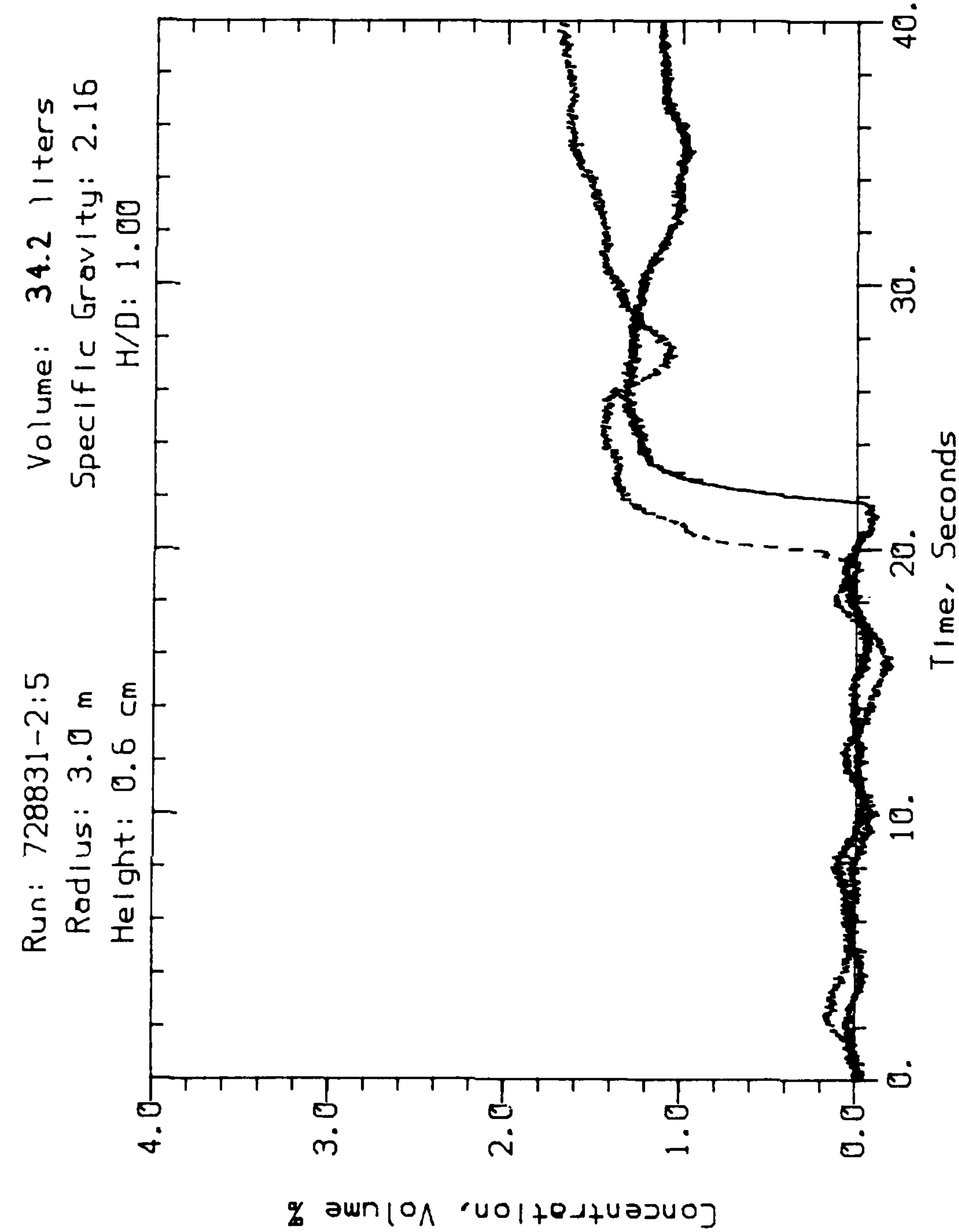
Run: 719834-5:7
Radius: 4.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 2.92
H/D: 1.00
0.
10.
20.
30.
40.
Time, Seconds
0.0
1.0
2.0
3.0
4.0
Concentration, Volume %


Run: 728831-2:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.16
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
15.
30.
45.
60.
0.
5.
10.
15.
20.

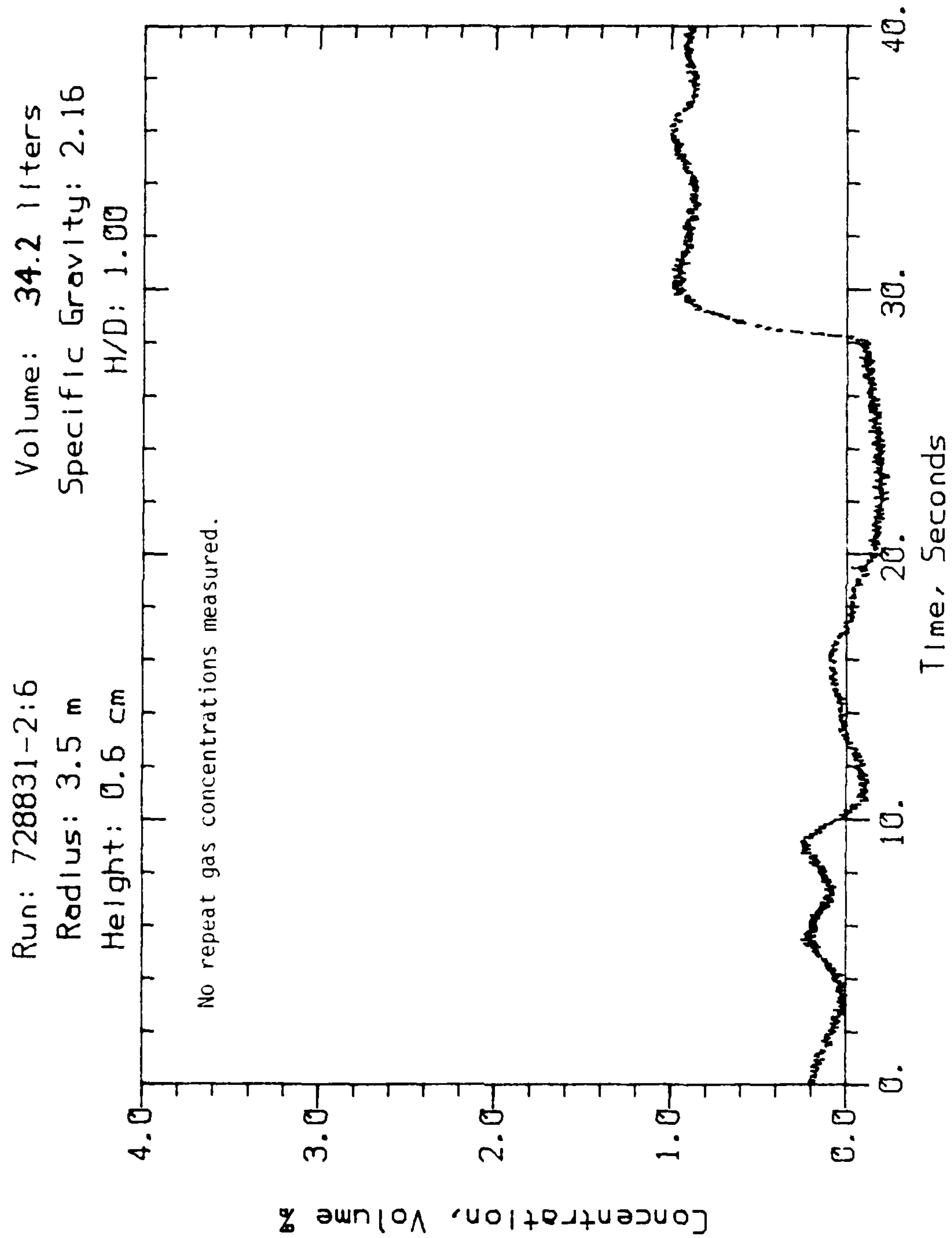


Run: 728831-2:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.16
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

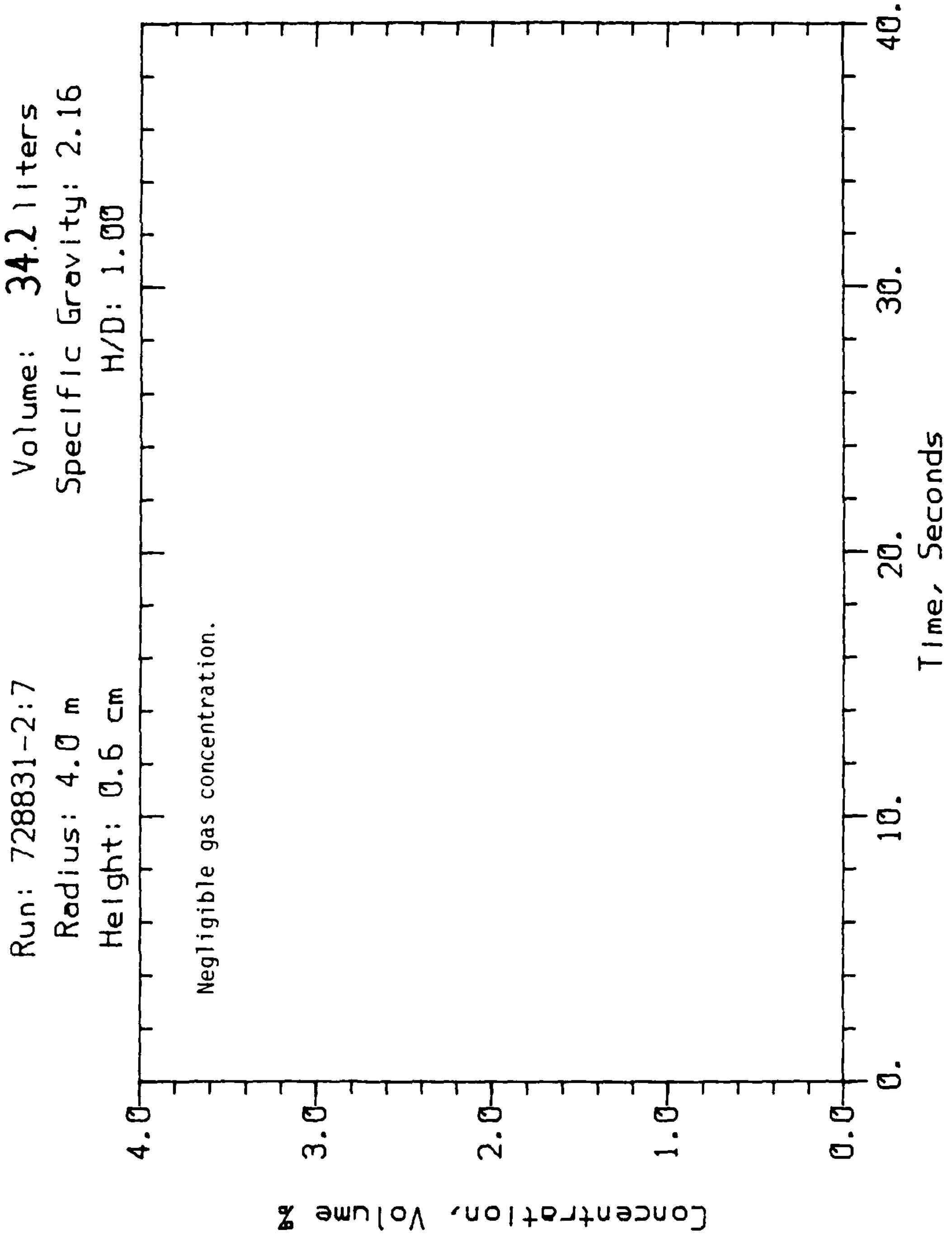

Run: 728831-2:3
Radius: 2.0 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.16
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.
5.
10.
15.
20.
Concentration, Volume %

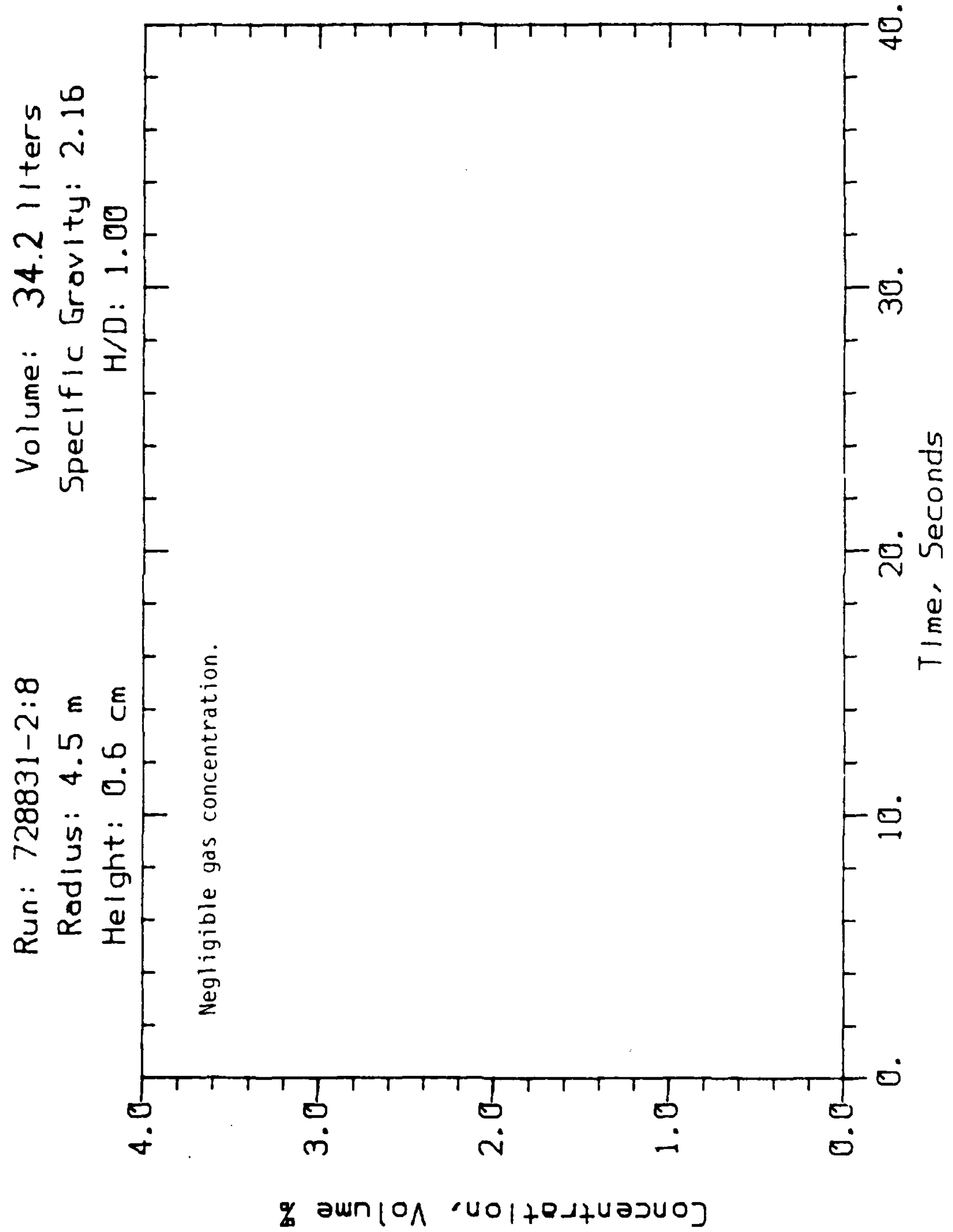


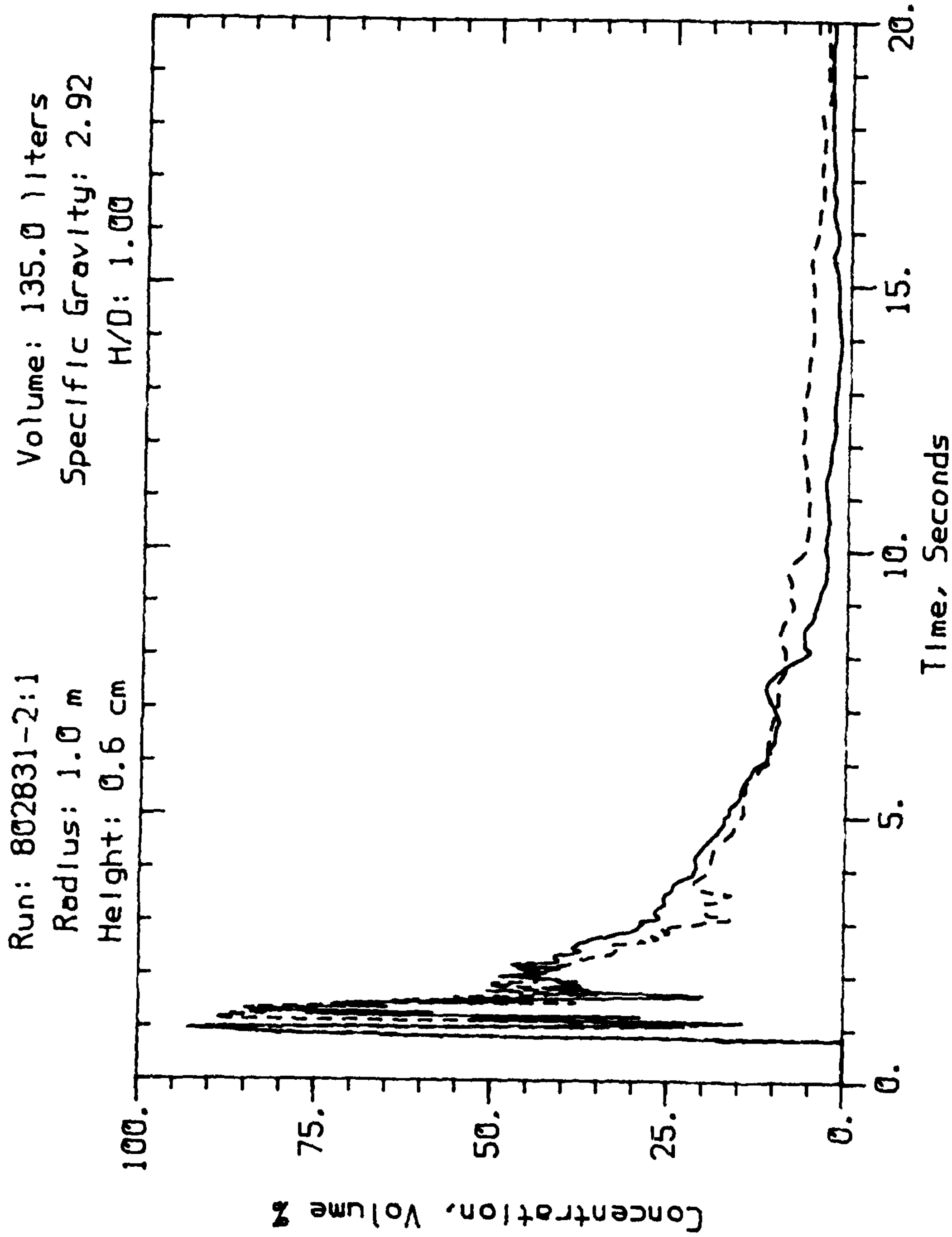
Run: 728831-2:5
Radius: 3.0 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.16
H/D: 1.00
Time, Seconds
Concentration, Volume %
0.
10.
20.
30.
40.
0.0
1.0
2.0
3.0
4.0



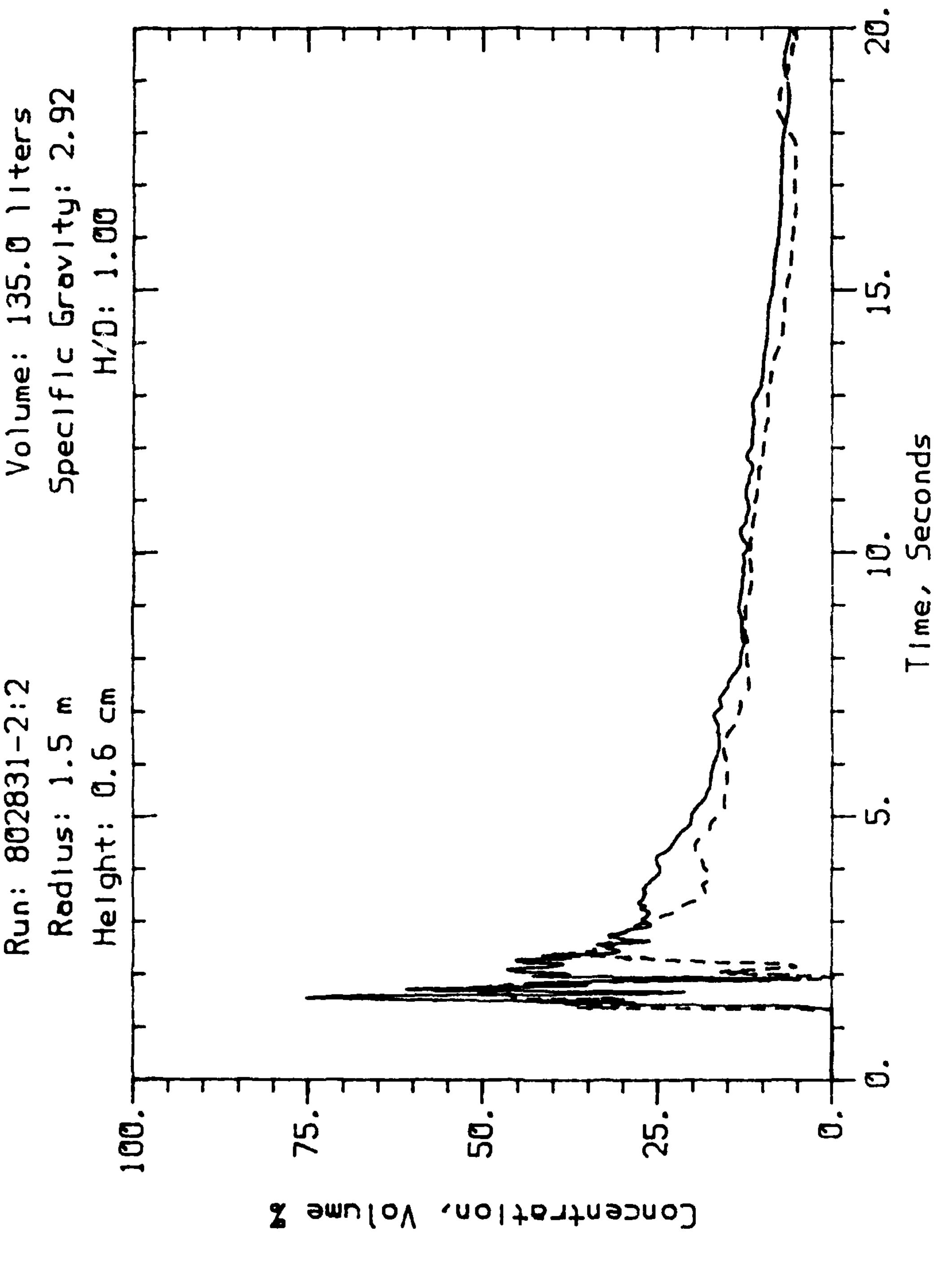
Run: 728831-2:6
Radius: 3.5 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.16
H/D: 1.00
No repeat gas concentrations measured.
Concentration, Volume %
4.0
3.0
2.0
1.0
0.0
0.
10.
20.
30.
40.
Time, Seconds

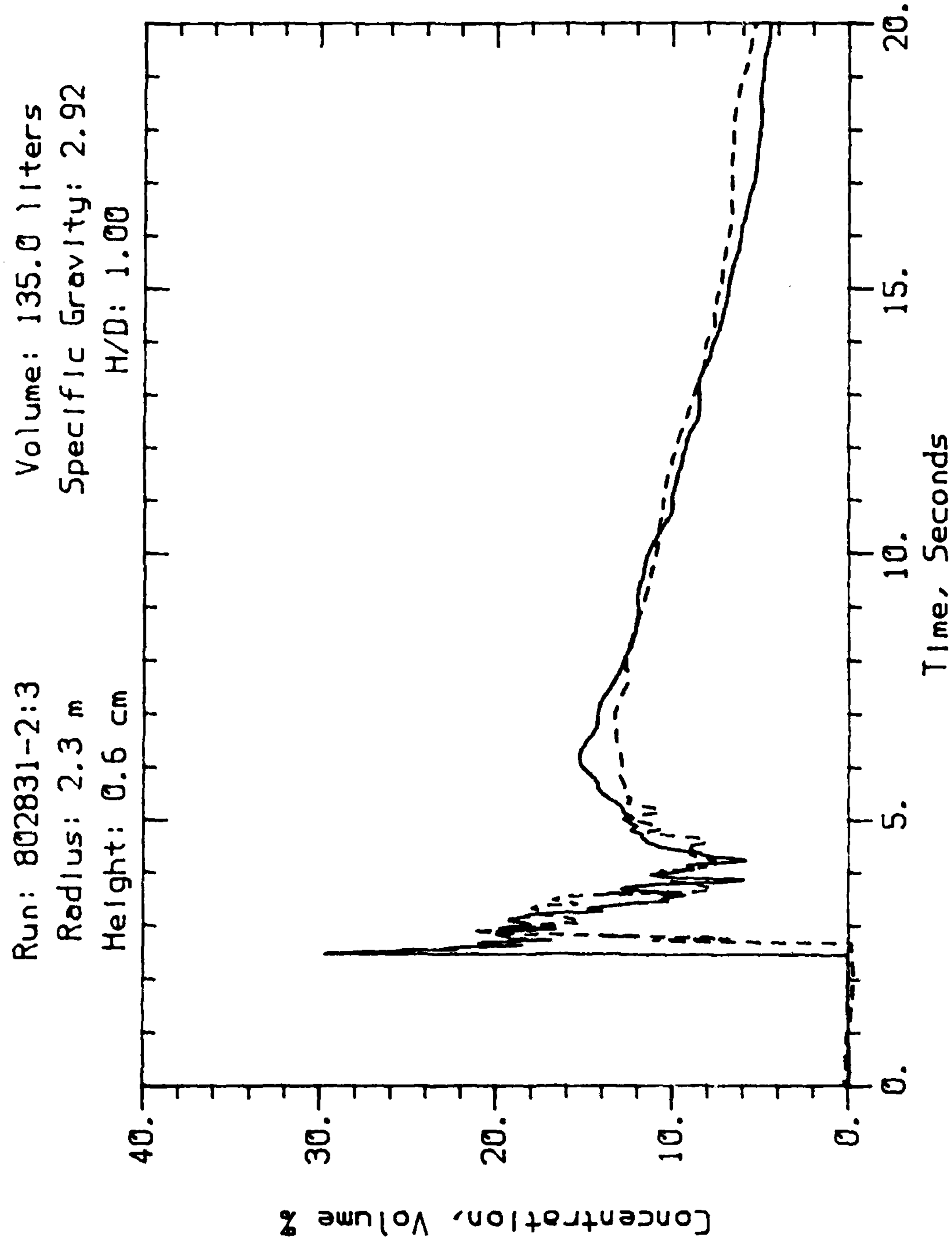

Run: 728831-2:7
Radius: 4.0 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.16
H/D: 1.00
Negligible gas concentration.
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
10.
20.
30.
40.


Run: 728831-2:8
Radius: 4.5 m
Height: 0.6 cm
Volume: 34.2 liters
Specific Gravity: 2.16
H/D: 1.00
Negligible gas concentration.
Concentration, Volume %
4.0
3.0
2.0
1.0
0.0
0.
10.
20.
30.
40.
Time, Seconds



Run: 802831-2:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
100.
75.
50.
25.
0.
Time, Seconds
0.
5.
10.
15.
20.

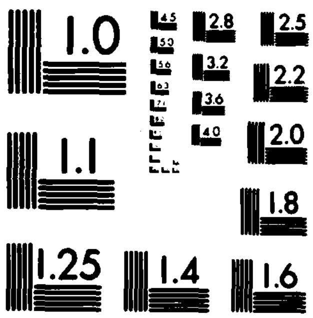

Run: 802831-2:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
100.
75.
50.
25.
0.
Time, Seconds
0.
5.
10.
15.
20.


Run: 802831-2:3
Radius: 2.3 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
10.
20.
30.
40.
0.
5.
10.
15.
20.

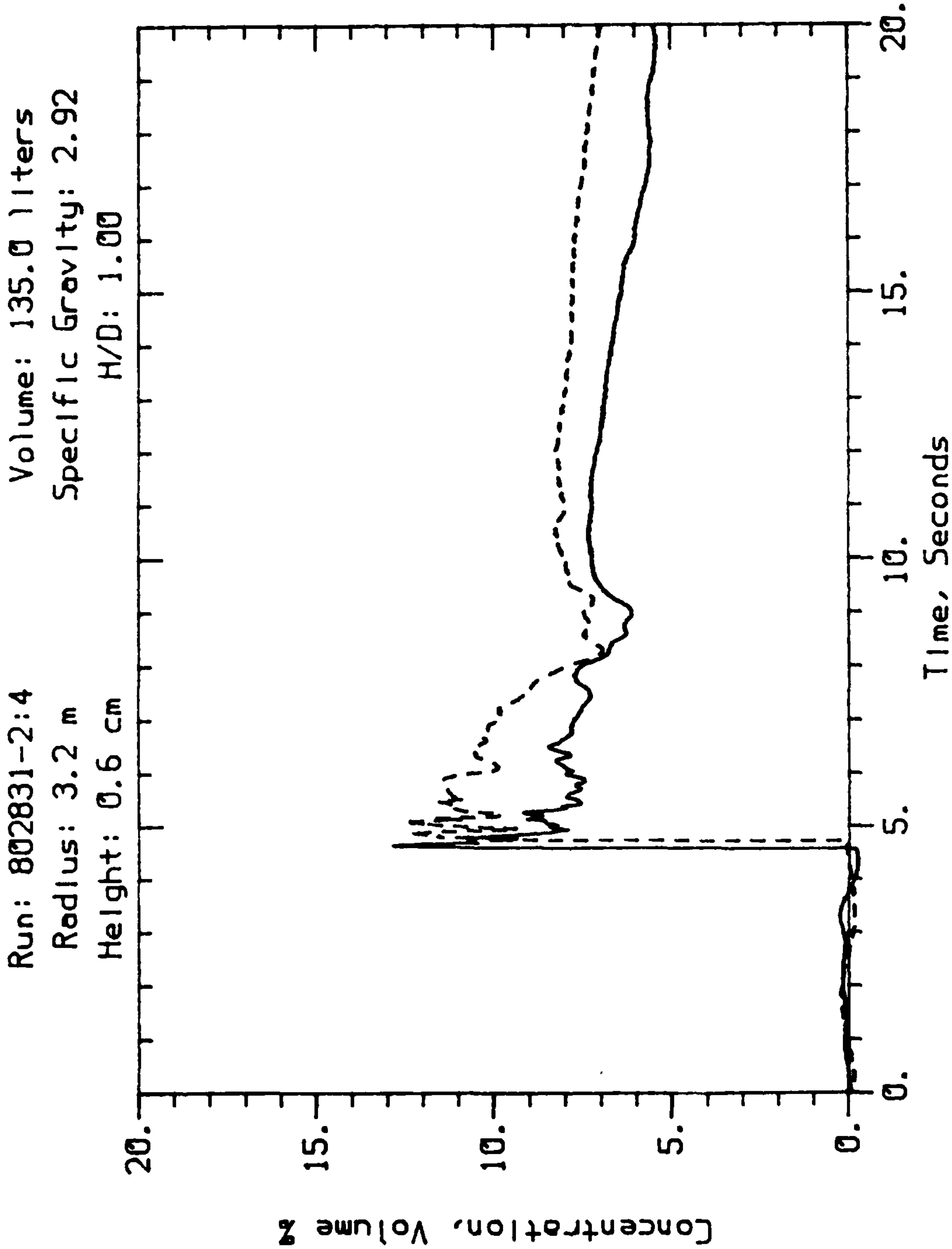
AD-A171 523 DEVELOPMENT OF AN ATMOSPHERIC DISPERSION MODEL FOR HEAVIER-THAN-AIR GAS M..(U) ARKANSAS UNIV FAYETTEVILLE DEPT OF CHEMICAL ENGINEERING J A HAVENS ET AL. MAY 85 3/3

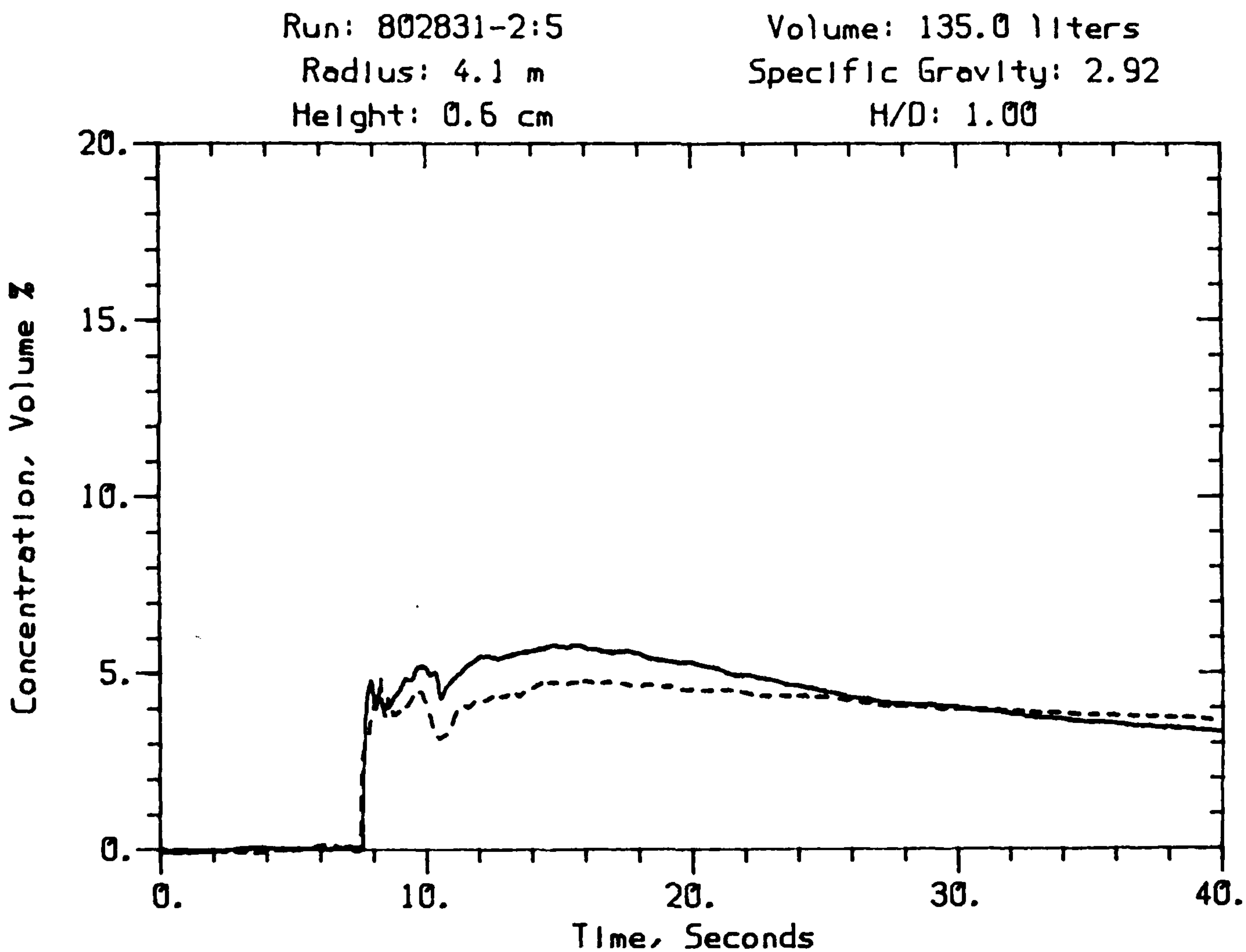
UNCLASSIFIED USCG-D-23-85 DTCG23-80-C-20029 F/G 20/4 NL

END
DATE
FILMED
10-86
DTIC

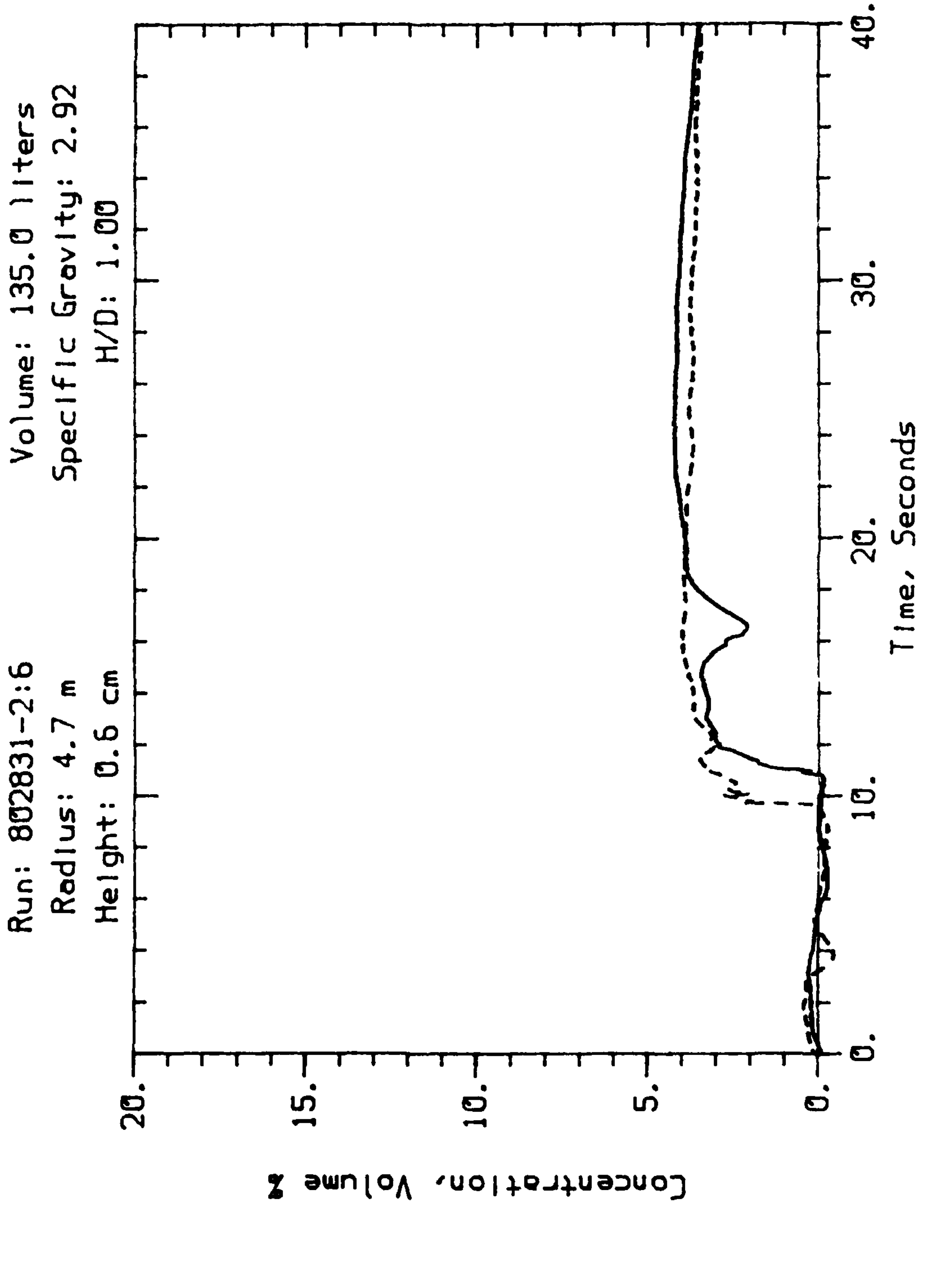


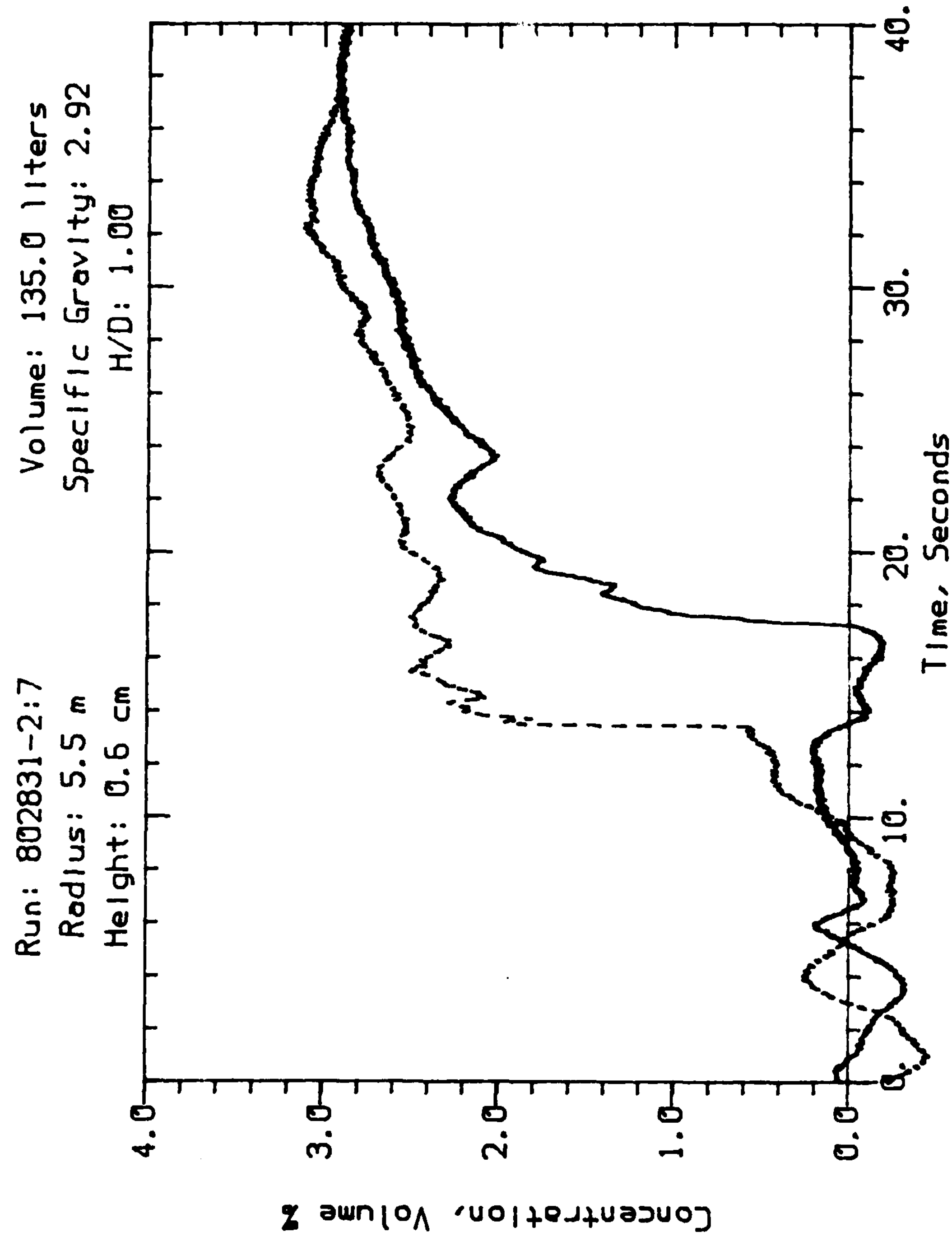
'CROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

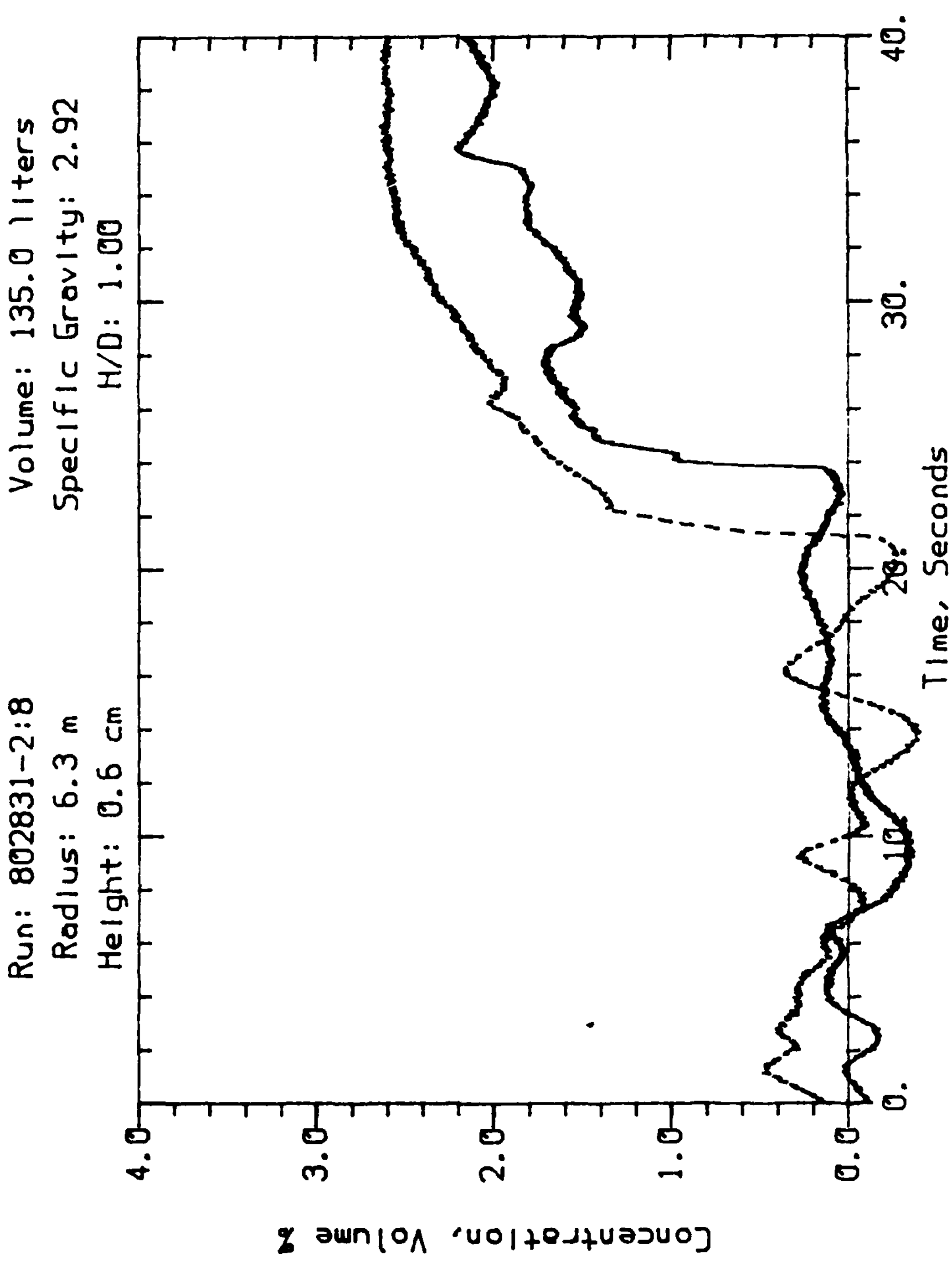

Run: 802831-2:4
Radius: 3.2 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
20.
15.
10.
5.
0.
Time, Seconds

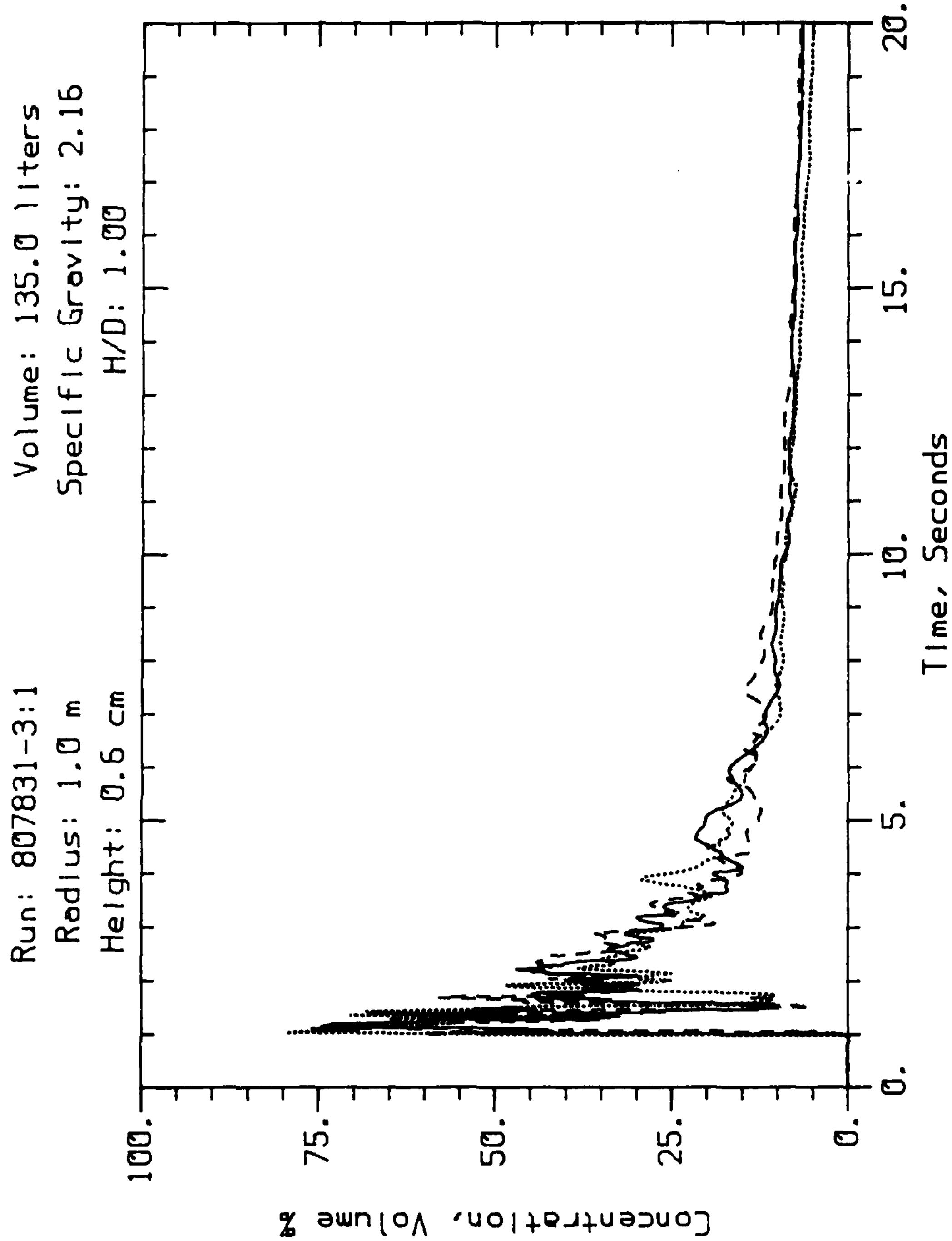


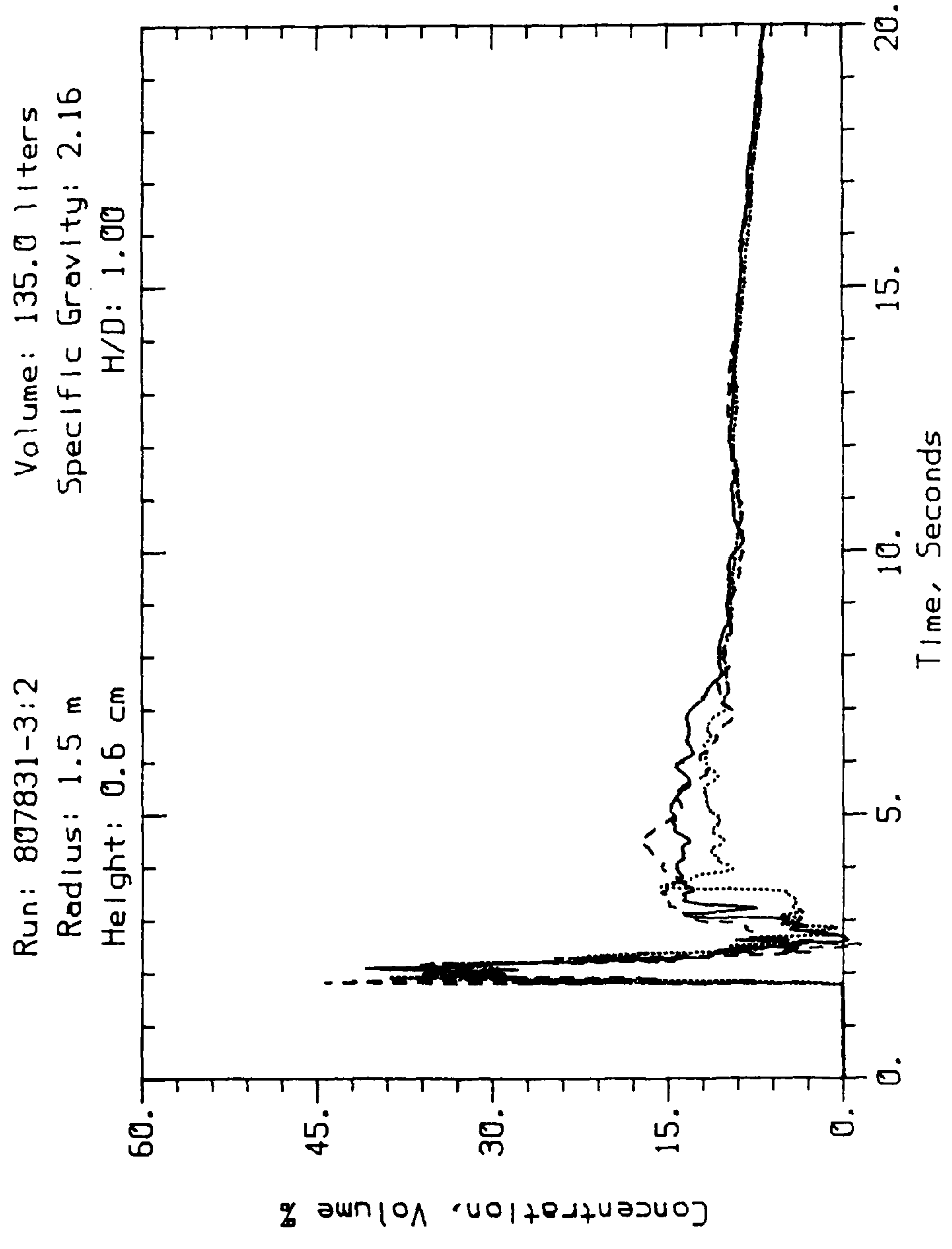
Run: 802831-2:5
Radius: 4.1 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
10.
20.
30.
40.


Run: 802831-2:6
Radius: 4.7 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.92
H/D: 1.00
0.
10.
20.
30.
40.
Time, Seconds
20.
15.
10.
5.
0.
Concentration, Volume %

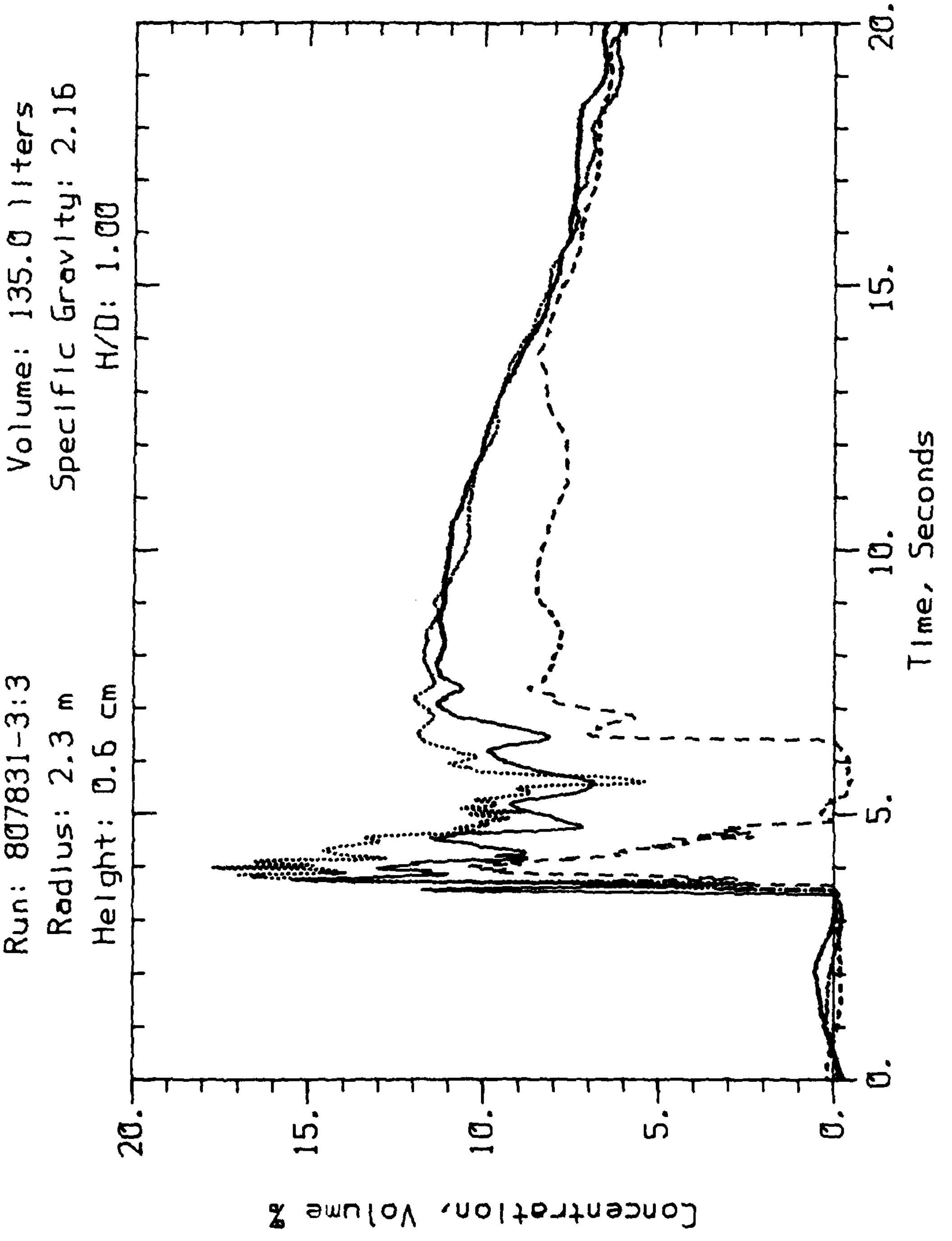

Run: 802831-2:7
Radius: 5.5 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
0.
10.
20.
30.
40.
Time, Seconds


Run: 802831-2:8
Radius: 6.3 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.92
H/D: 1.00
Concentration, Volume %
Time, Seconds
0.
10.
20.
30.
40.
0.0
1.0
2.0
3.0
4.0

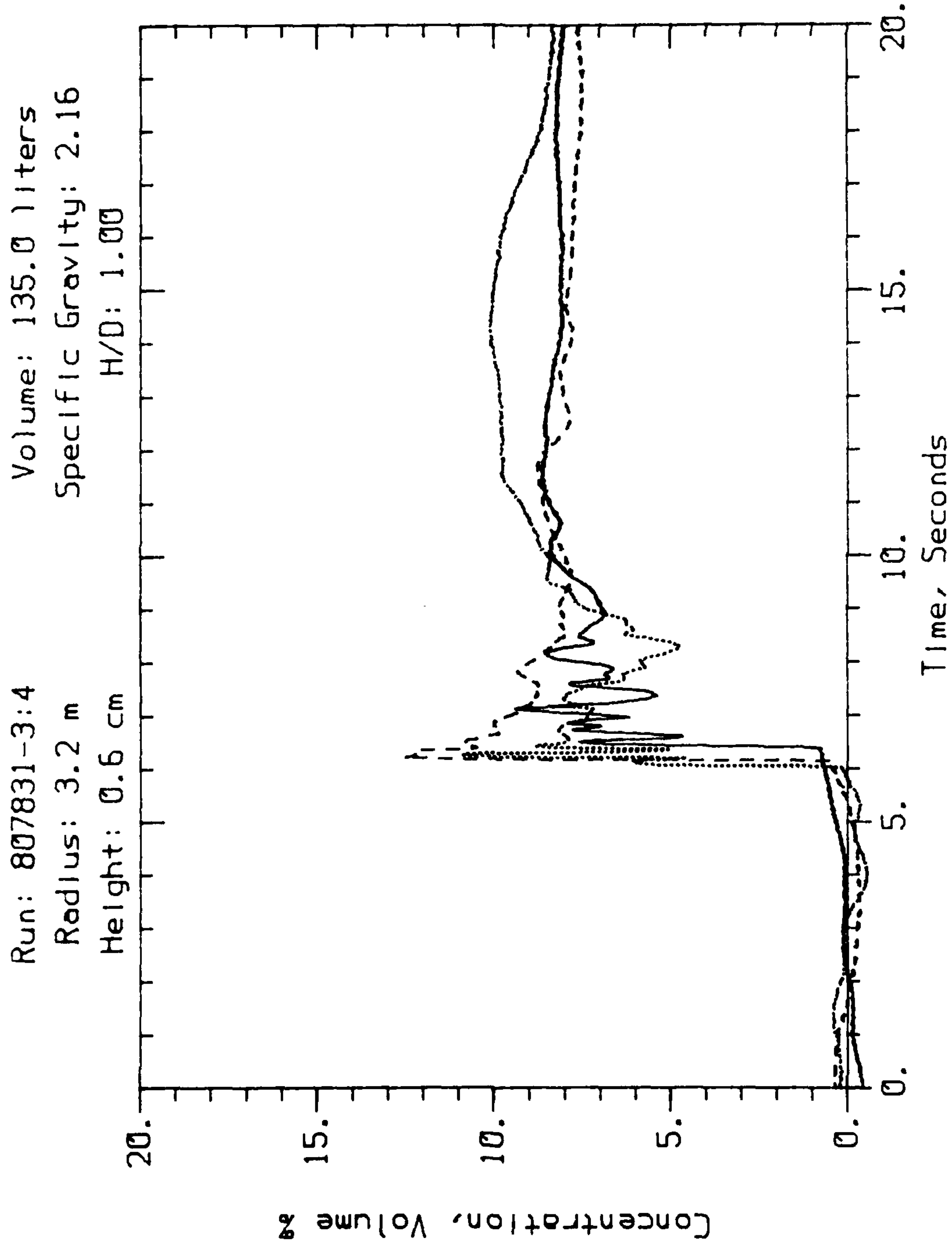

Run: 807831-3:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.16
H/D: 1.00
100.
75.
50.
25.
0.
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

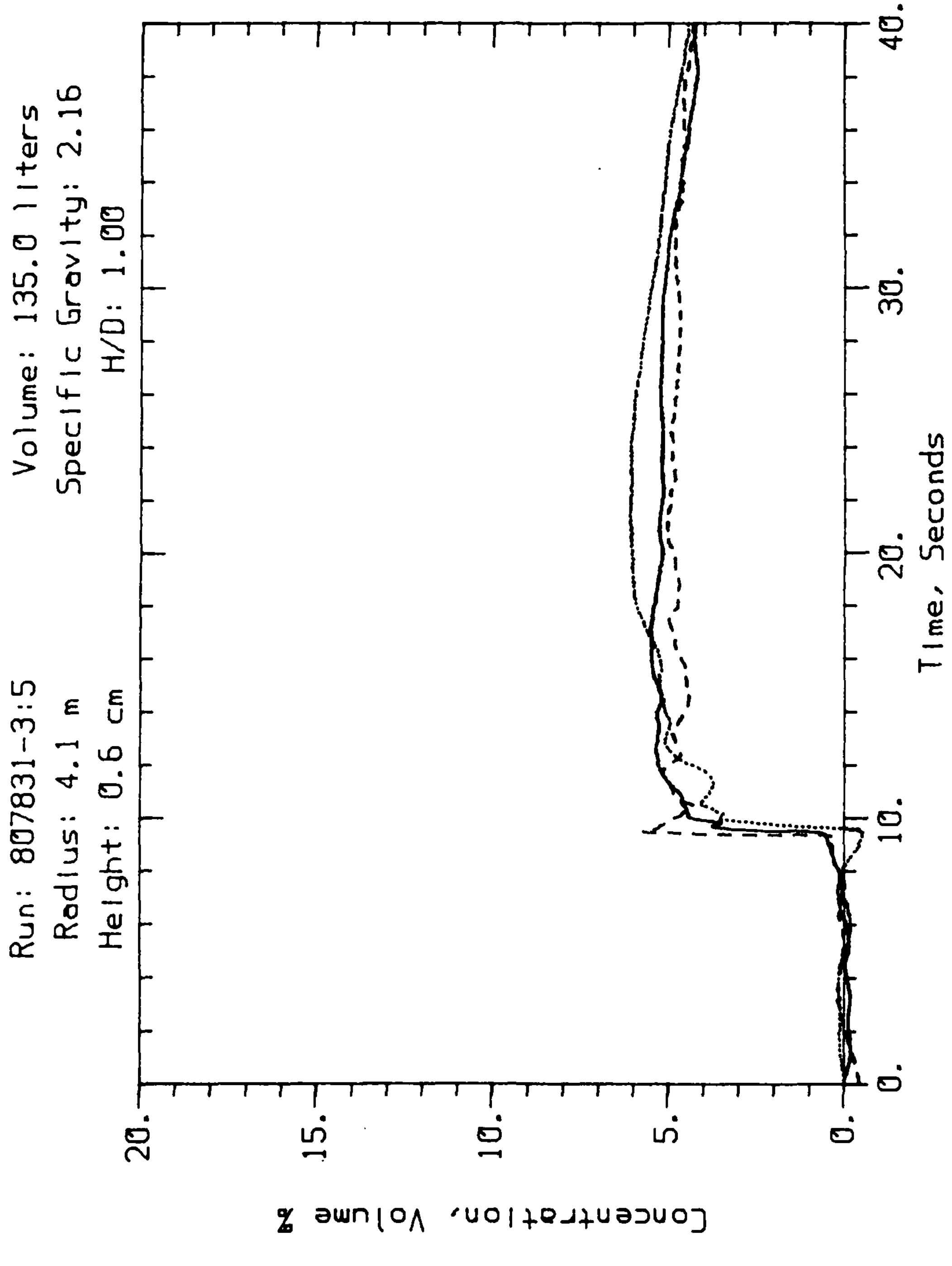


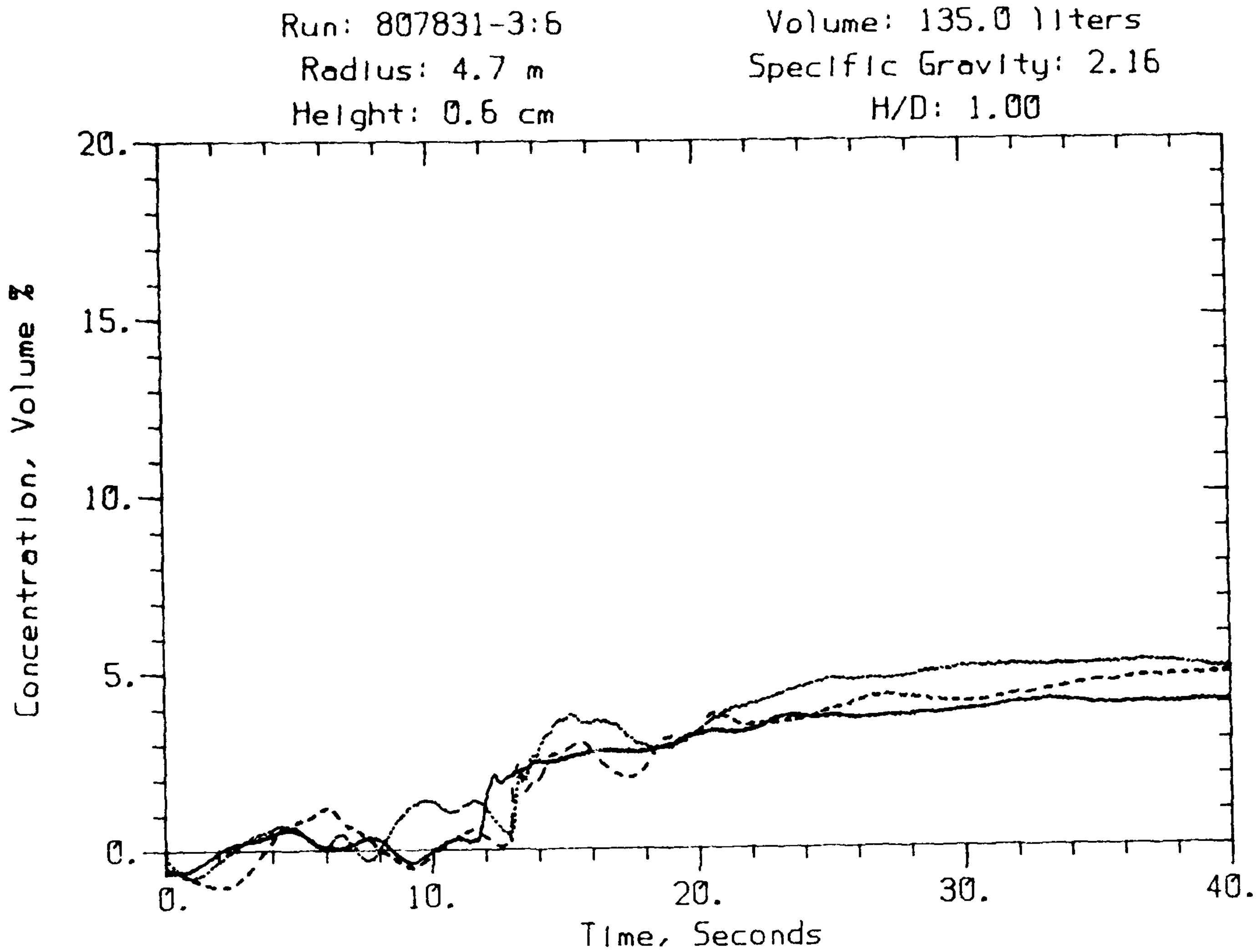
Run: 807831-3:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.16
H/D: 1.00
Concentration, Volume %
0.
15.
30.
45.
60.
Time, Seconds
0.
5.
10.
15.
20.

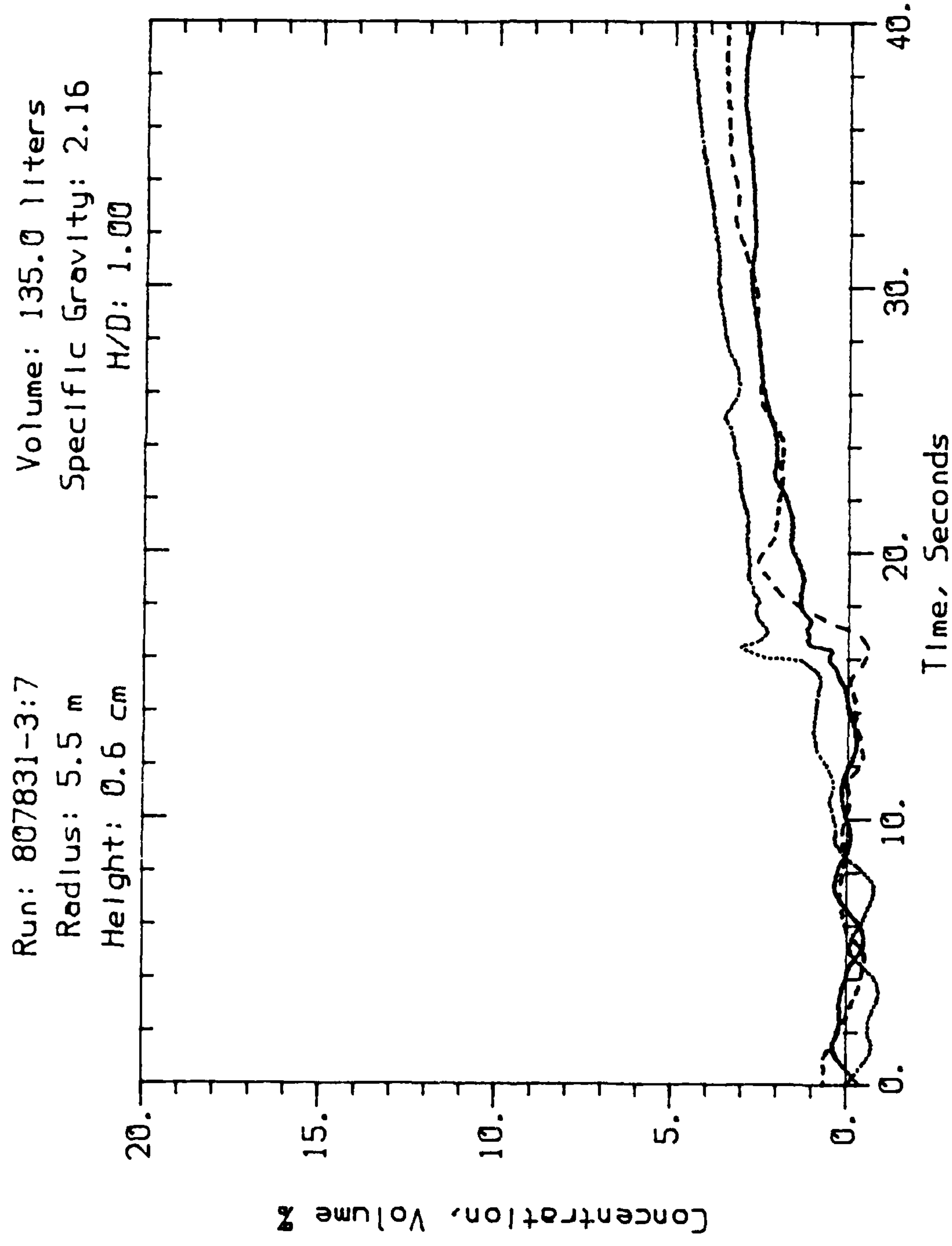


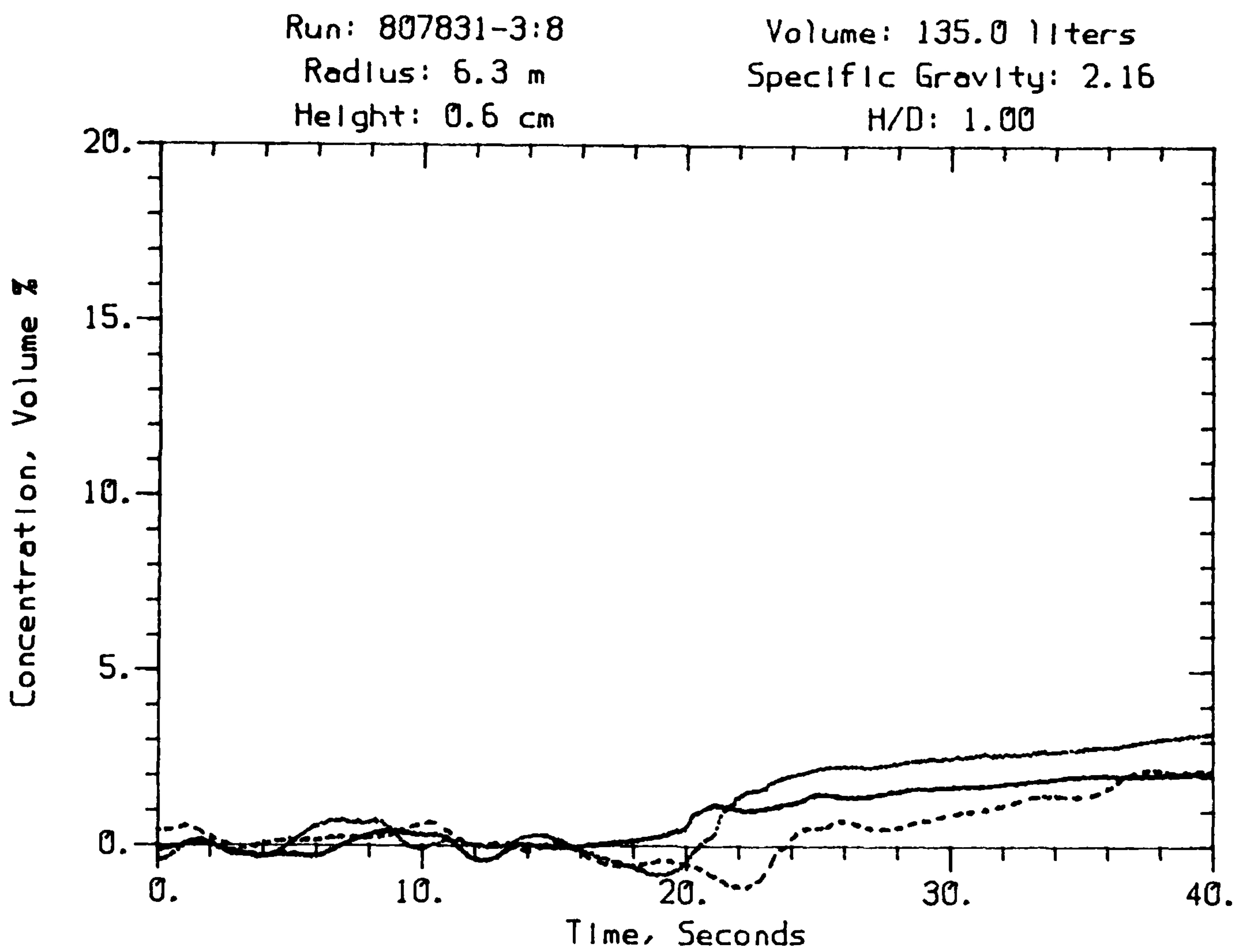
Run: 807831-3:3
Radius: 2.3 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.16
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
Concentration, Volume %

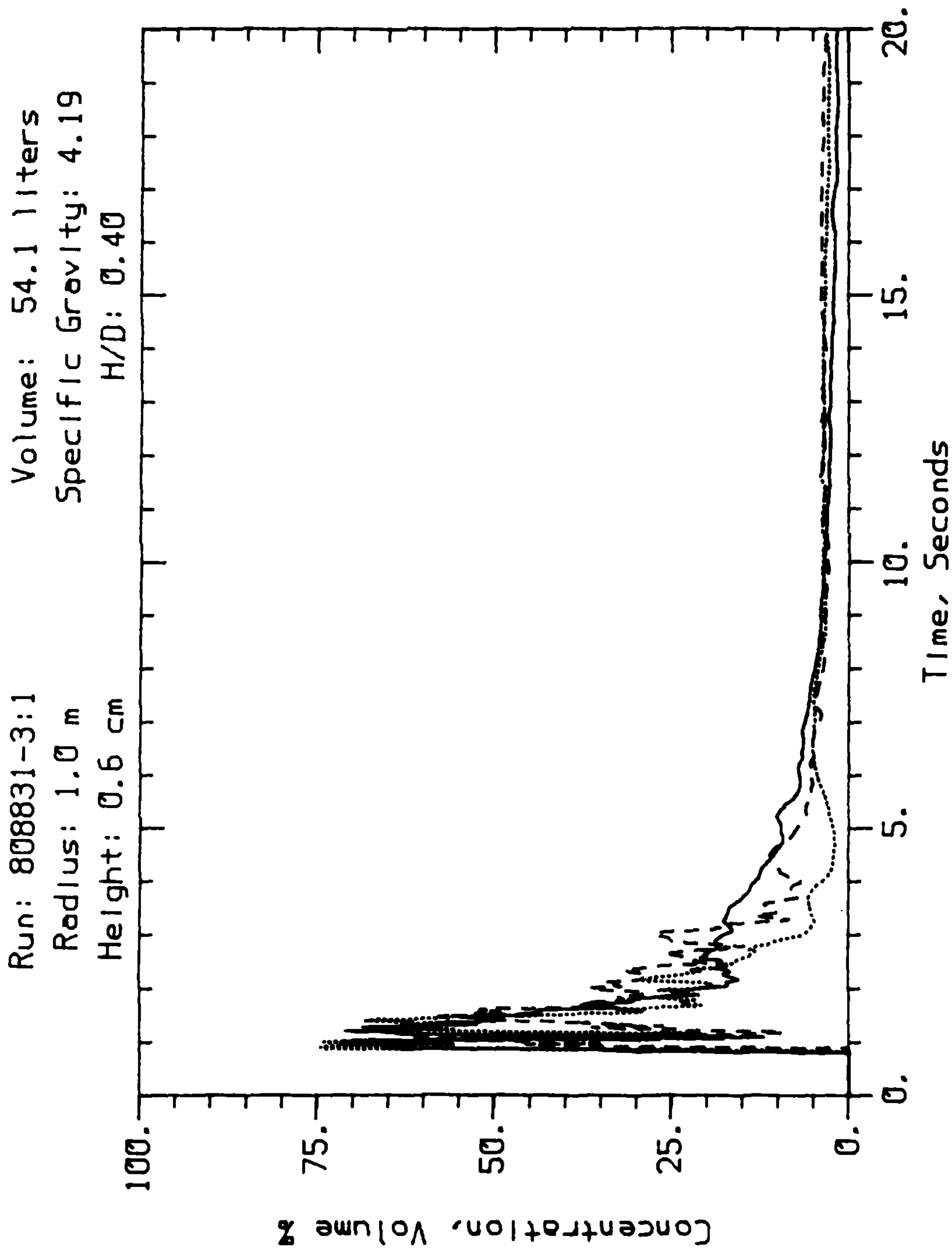

Run: 807831-3:4
Radius: 3.2 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.16
H/D: 1.00
0.
5.
10.
15.
20.
Time, Seconds
0.
5.
10.
15.
20.
Concentration, Volume %

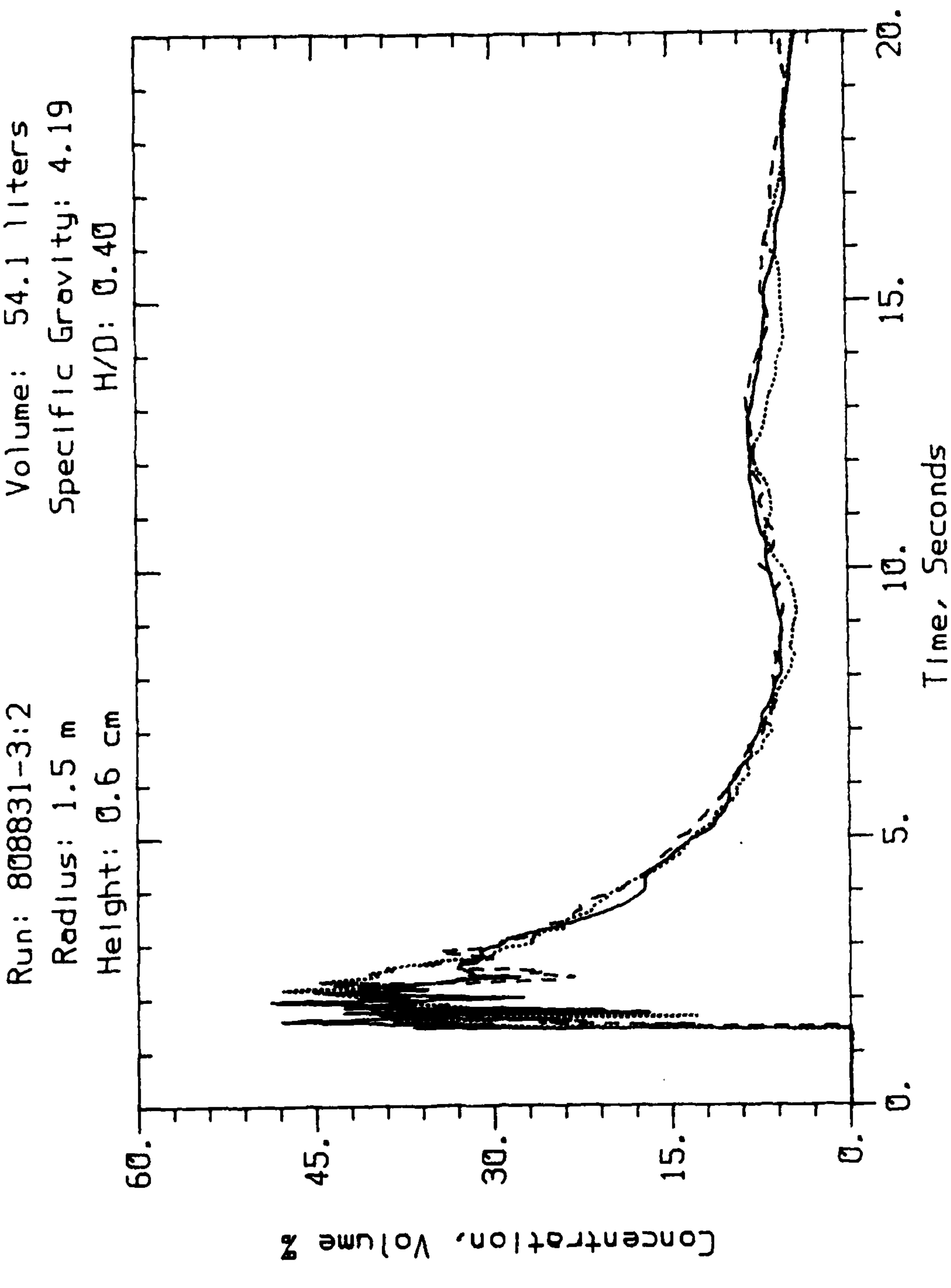

Run: 807831-3:5
Radius: 4.1 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.16
H/D: 1.00
0.
10.
20.
30.
40.
Time, Seconds
0.
5.
10.
15.
20.
Concentration, Volume %

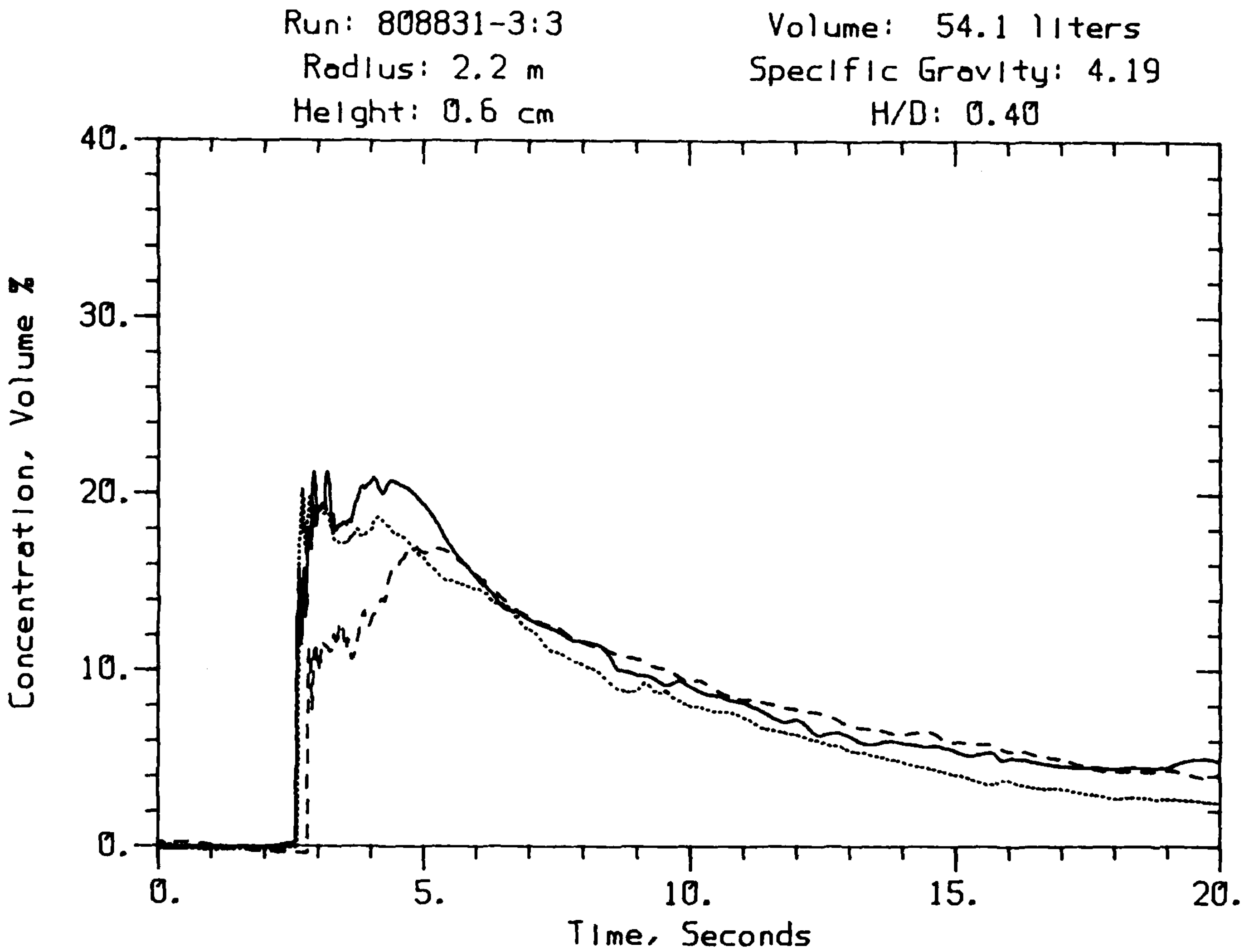

Run: 807831-3:6
Radius: 4.7 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.16
H/D: 1.00
Concentration, Volume %
20.
15.
10.
5.
0.
0.
10.
20.
30.
40.
Time, Seconds

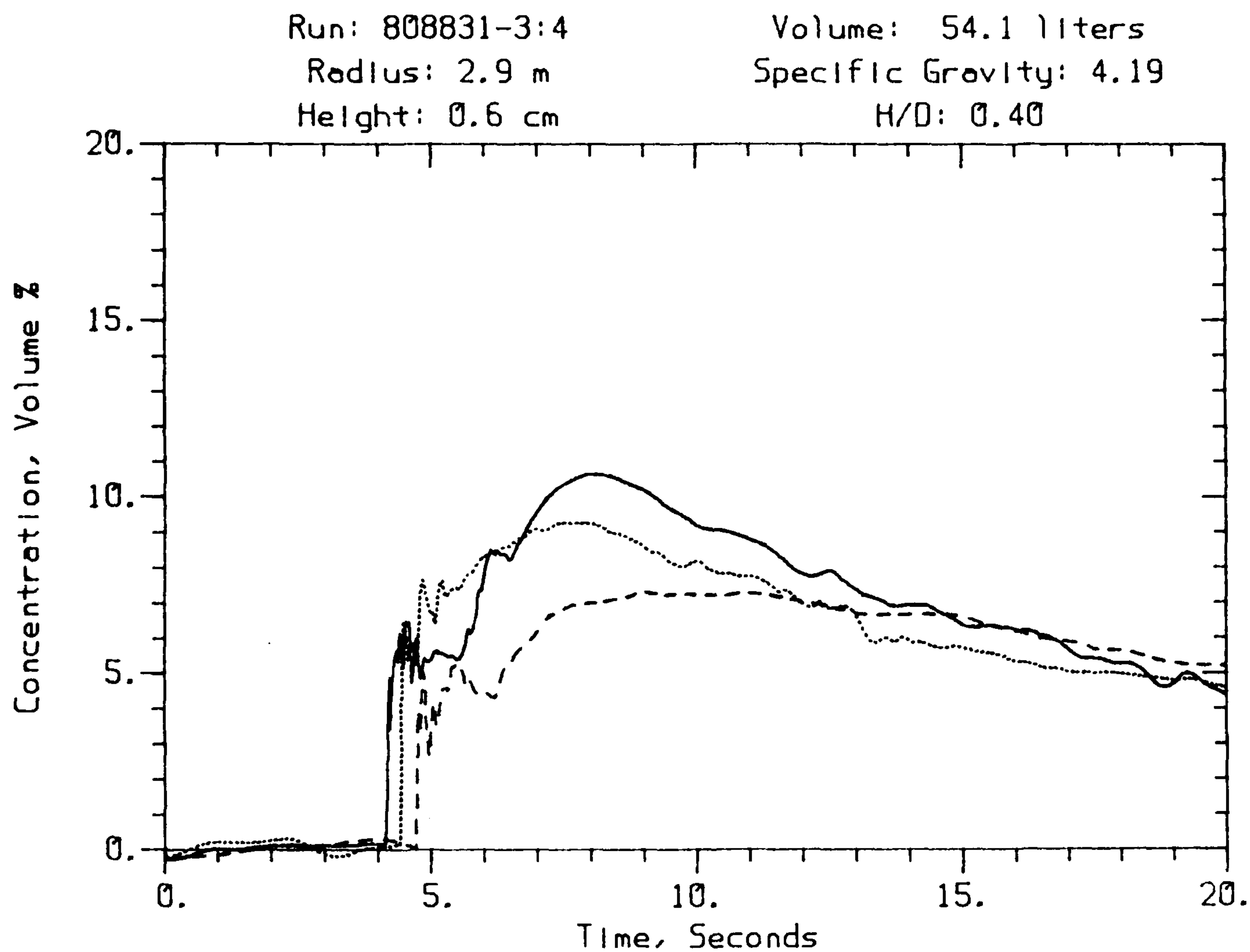

Run: 807831-3:7
Radius: 5.5 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.16
H/D: 1.00
0.
10.
20.
30.
40.
Time, Seconds
0.
5.
10.
15.
20.
Concentration, Volume %

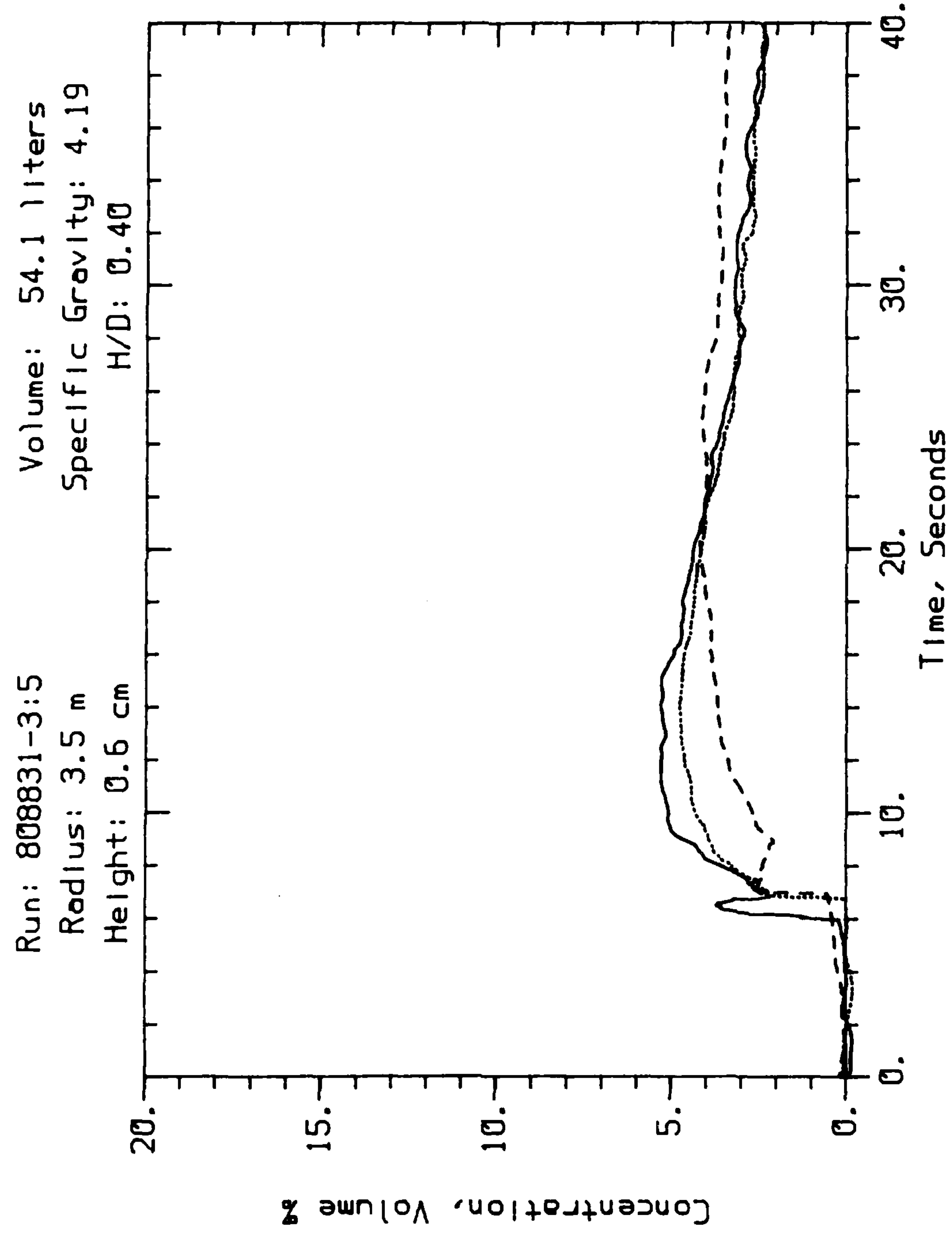

Run: 807831-3:8
Radius: 6.3 m
Height: 0.6 cm
Volume: 135.0 liters
Specific Gravity: 2.16
H/D: 1.00
20.
15.
10.
5.
0.
Concentration, Volume %
0.
10.
20.
30.
40.
Time, Seconds

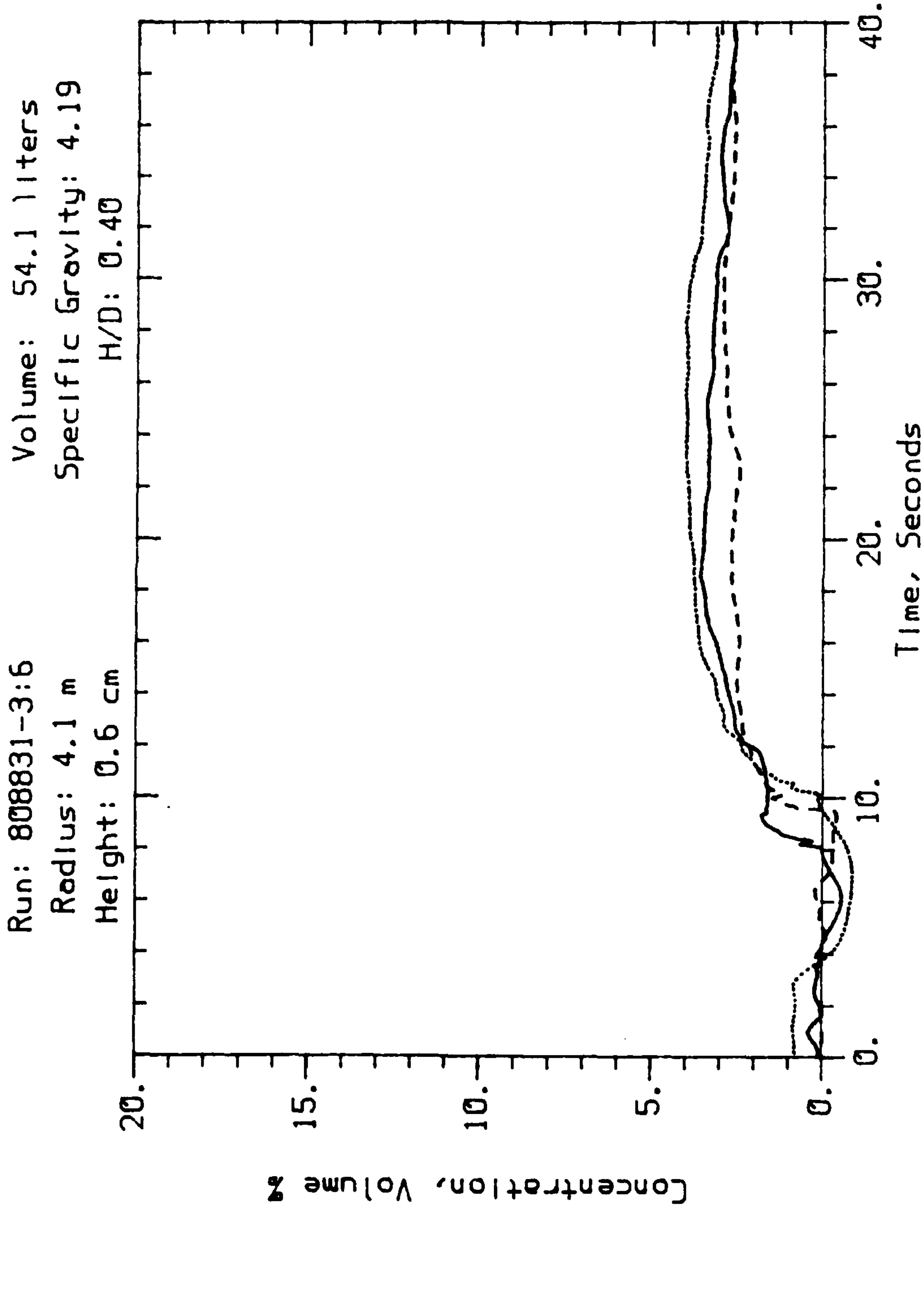

Run: 808831-3:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 0.40
Concentration, Volume %
100.
75.
50.
25.
0.
Time, Seconds
0.
5.
10.
15.
20.


Run: 808831-3:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 0.40
Concentration, Volume %
60.
45.
30.
15.
0.
0.
5.
10.
15.
20.
Time, Seconds

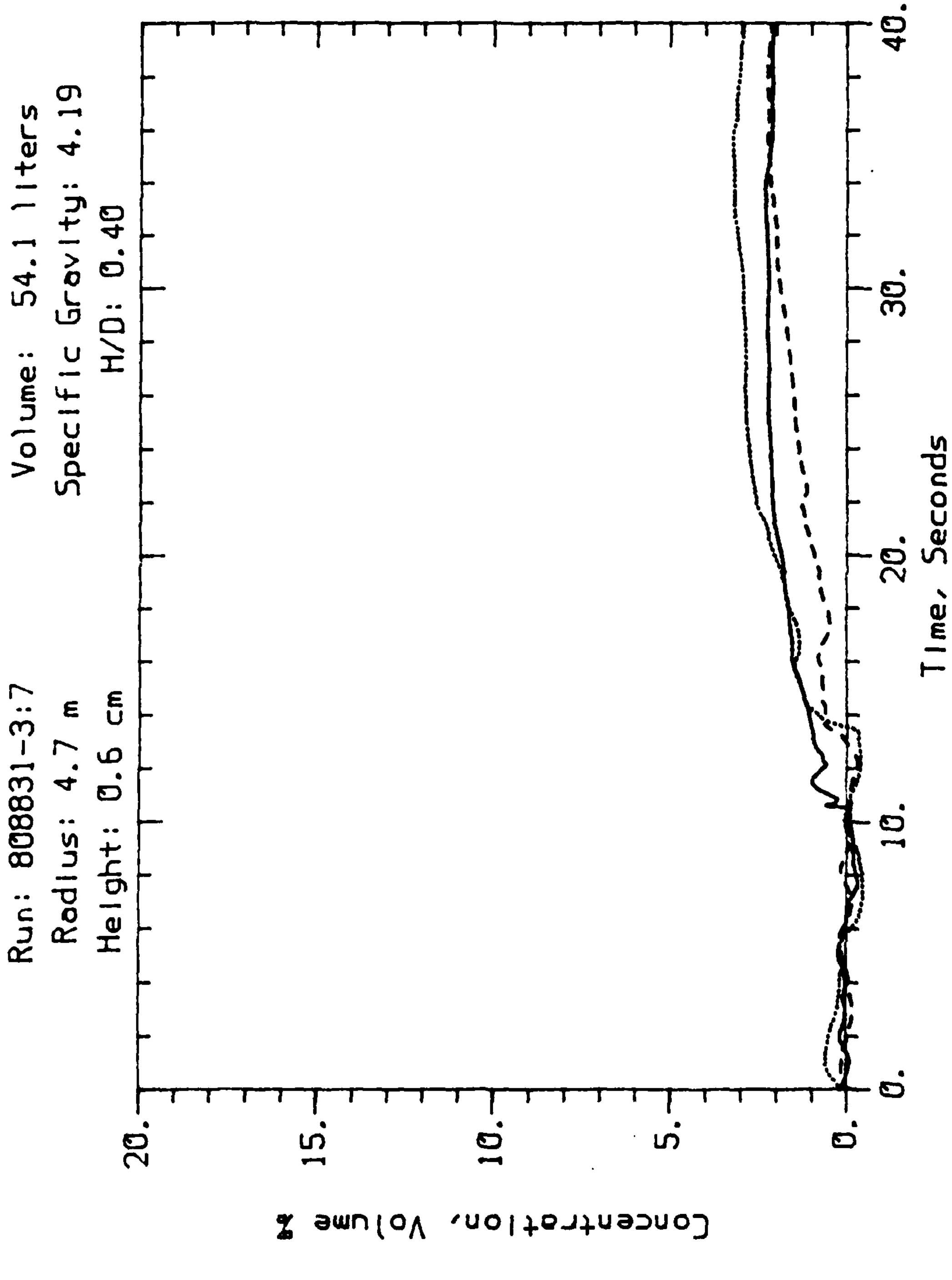

Run: 808831-3:3
Radius: 2.2 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 0.40
Concentration, Volume %
40.
30.
20.
10.
0.
0.
5.
10.
15.
20.
Time, Seconds

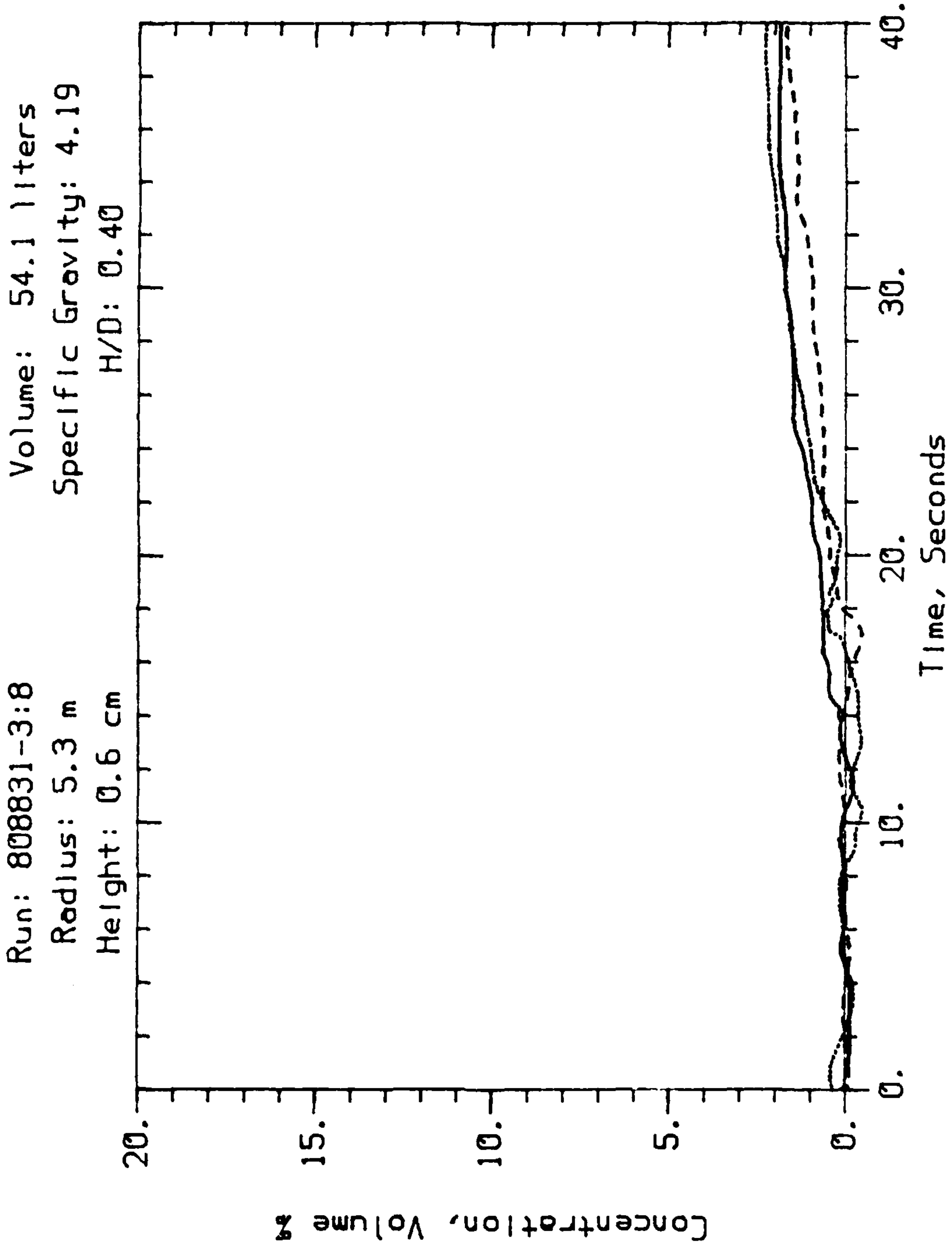

Run: 808831-3:4
Radius: 2.9 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 0.40
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

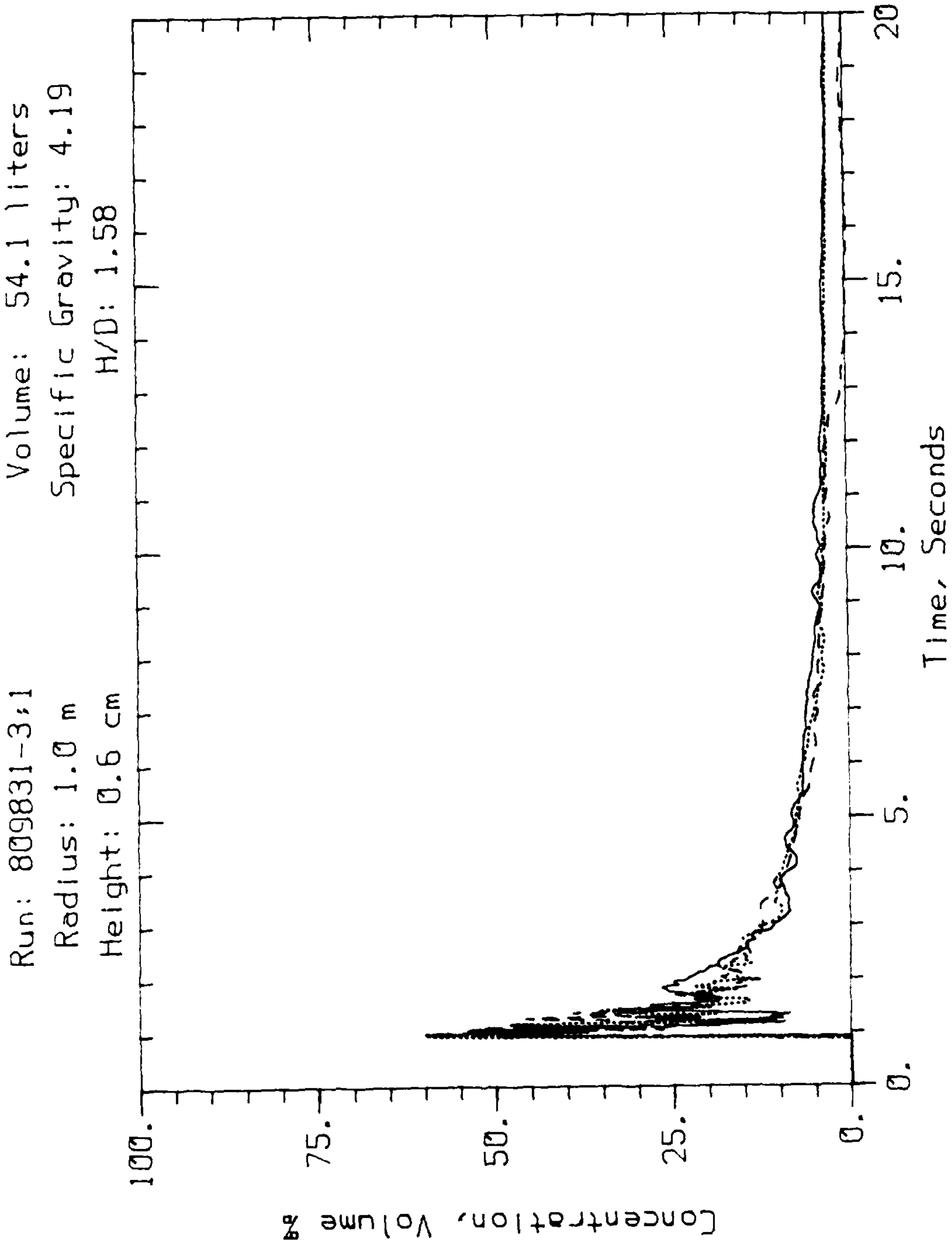

Run: 808831-3:5
Radius: 3.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 0.40
0.
10.
20.
30.
40.
Time, Seconds
0.
5.
10.
15.
20.
Concentration, Volume %

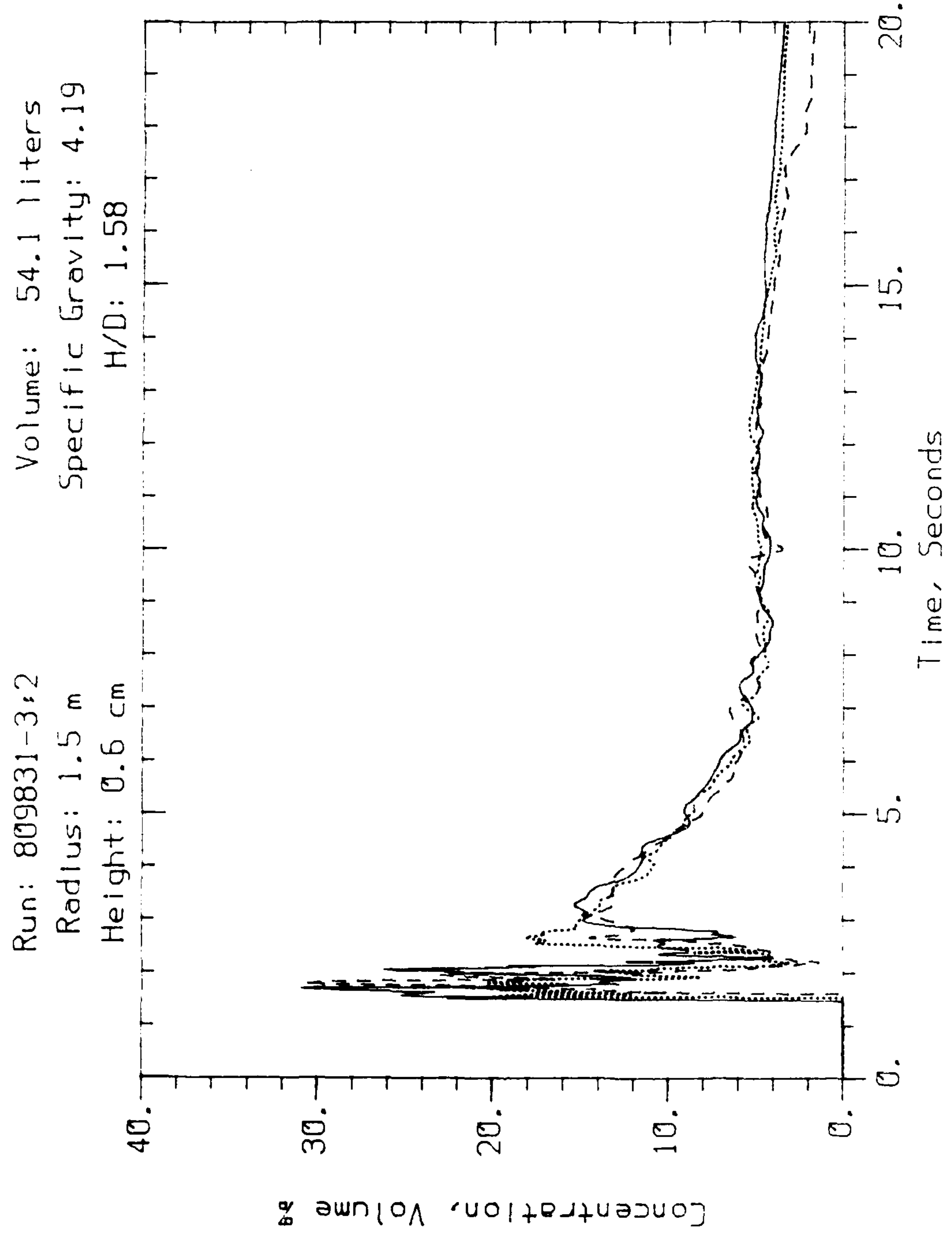


Run: 808831-3:6
Radius: 4.1 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 0.40
Time, Seconds
Concentration, Volume %
0.
5.
10.
15.
20.
0.
10.
20.
30.
40.

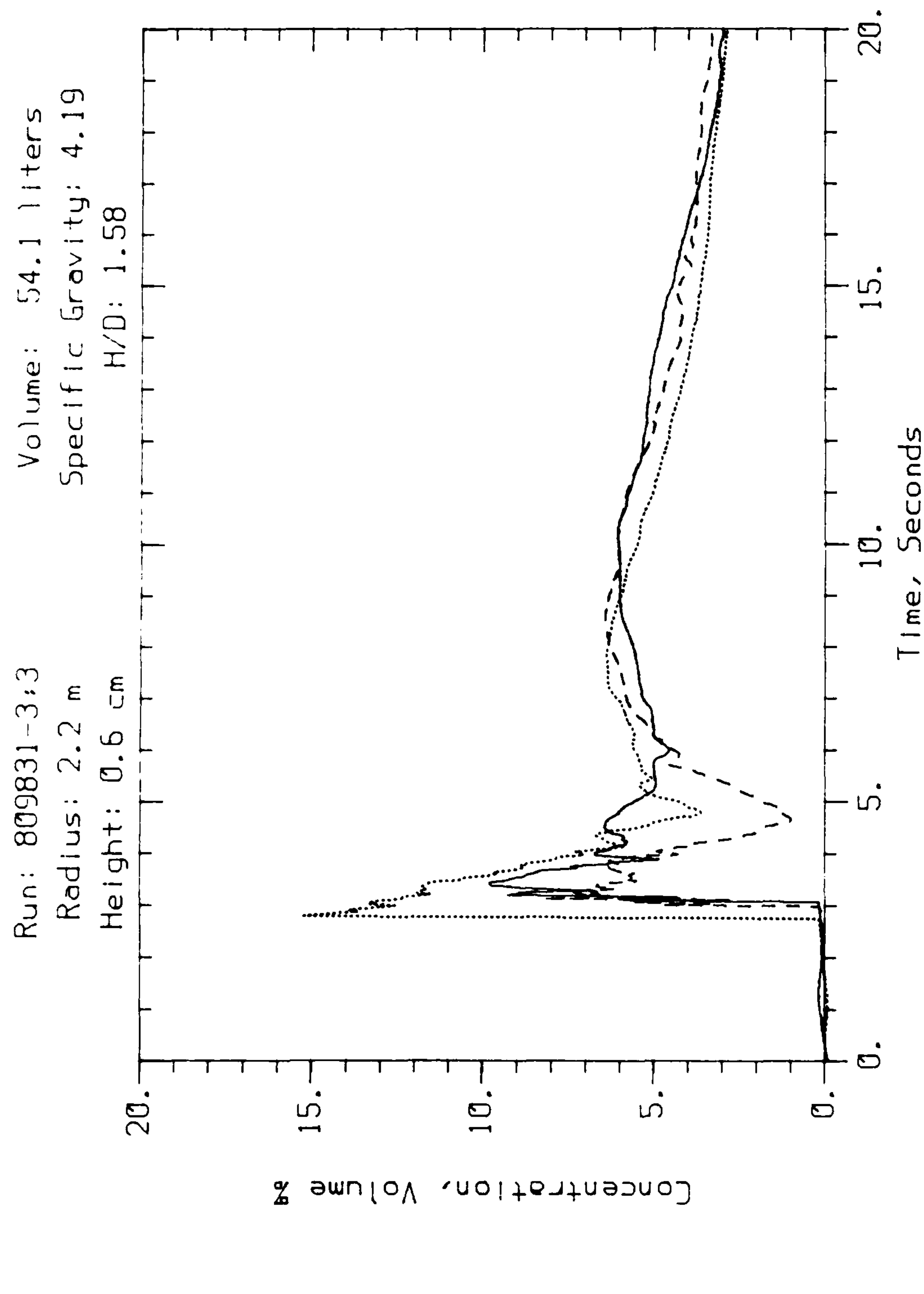

Run: 808831-3:7
Radius: 4.7 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 0.40
Concentration, Volume %
20.
15.
10.
5.
0.
Time, Seconds
0.
10.
20.
30.
40.

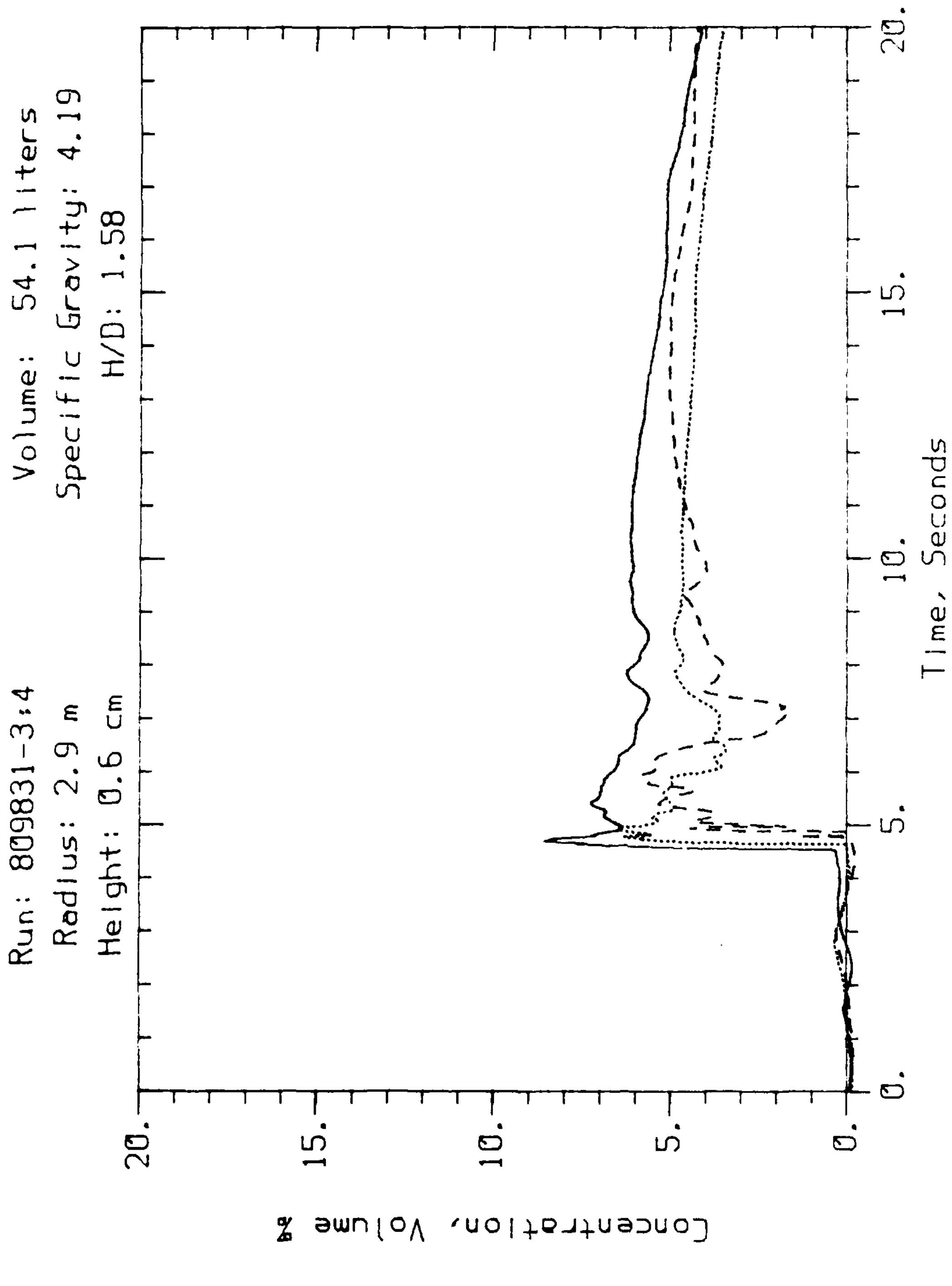

Run: 808831-3:8
Radius: 5.3 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 0.40
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds
0.
10.
20.
30.
40.


Run: 809831-3;1
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
Time, Seconds
0.
25.
50.
75.
100.
0.
5.
10.
15.
20.

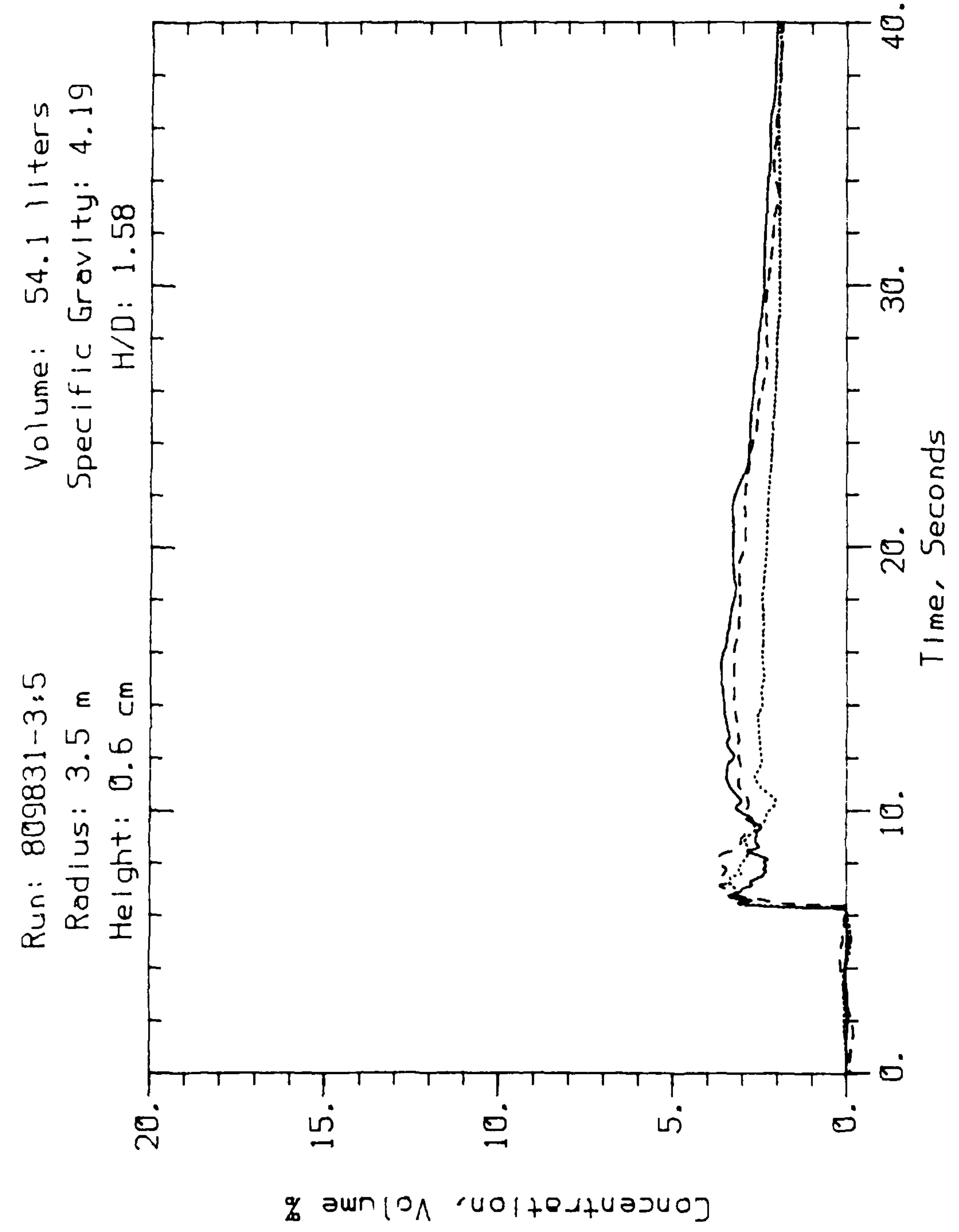


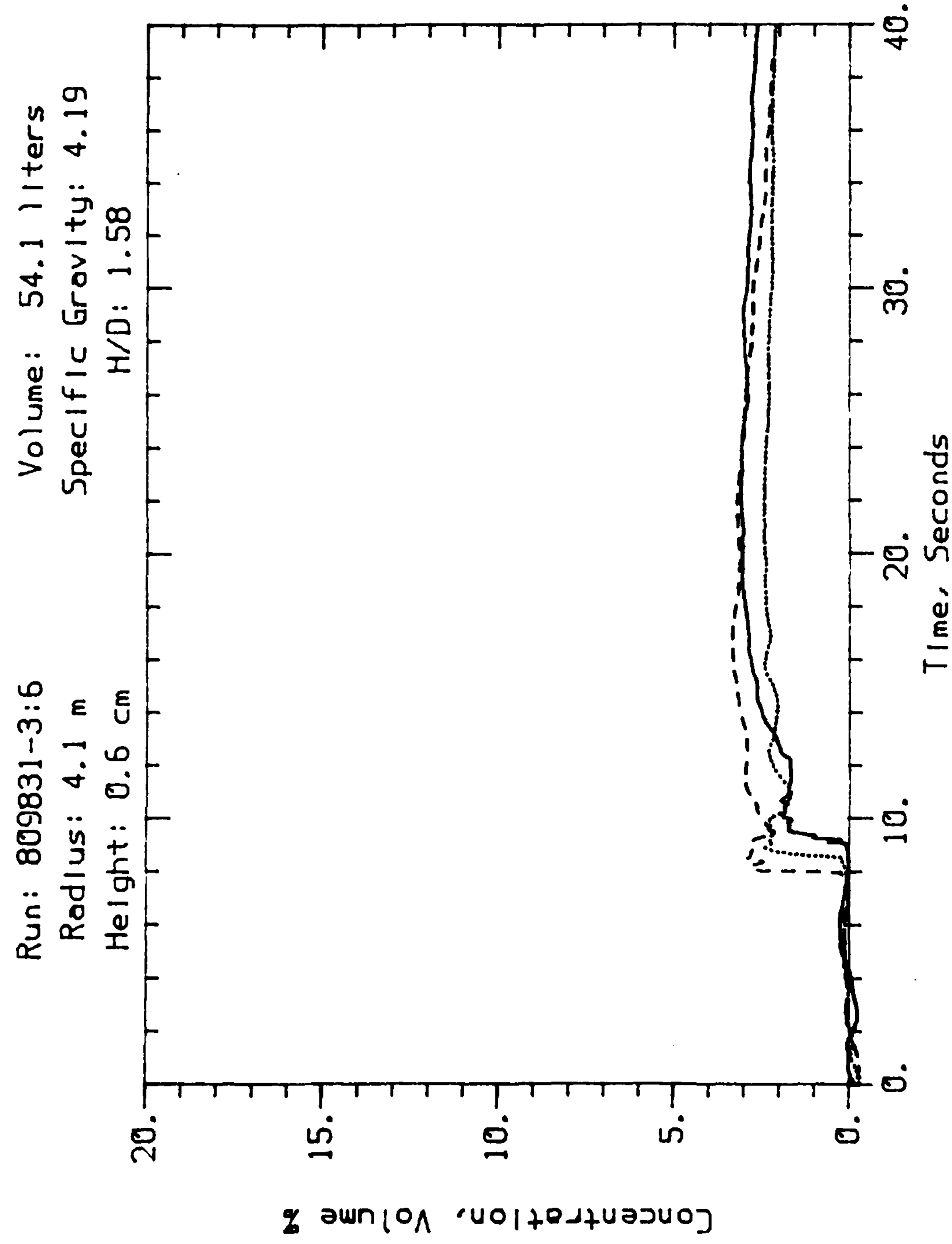
Run: 809831-3:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
Time, Seconds
0.
10.
20.
30.
40.
0.
5.
10.
15.
20.


Run: 809831-3;3
Radius: 2.2 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

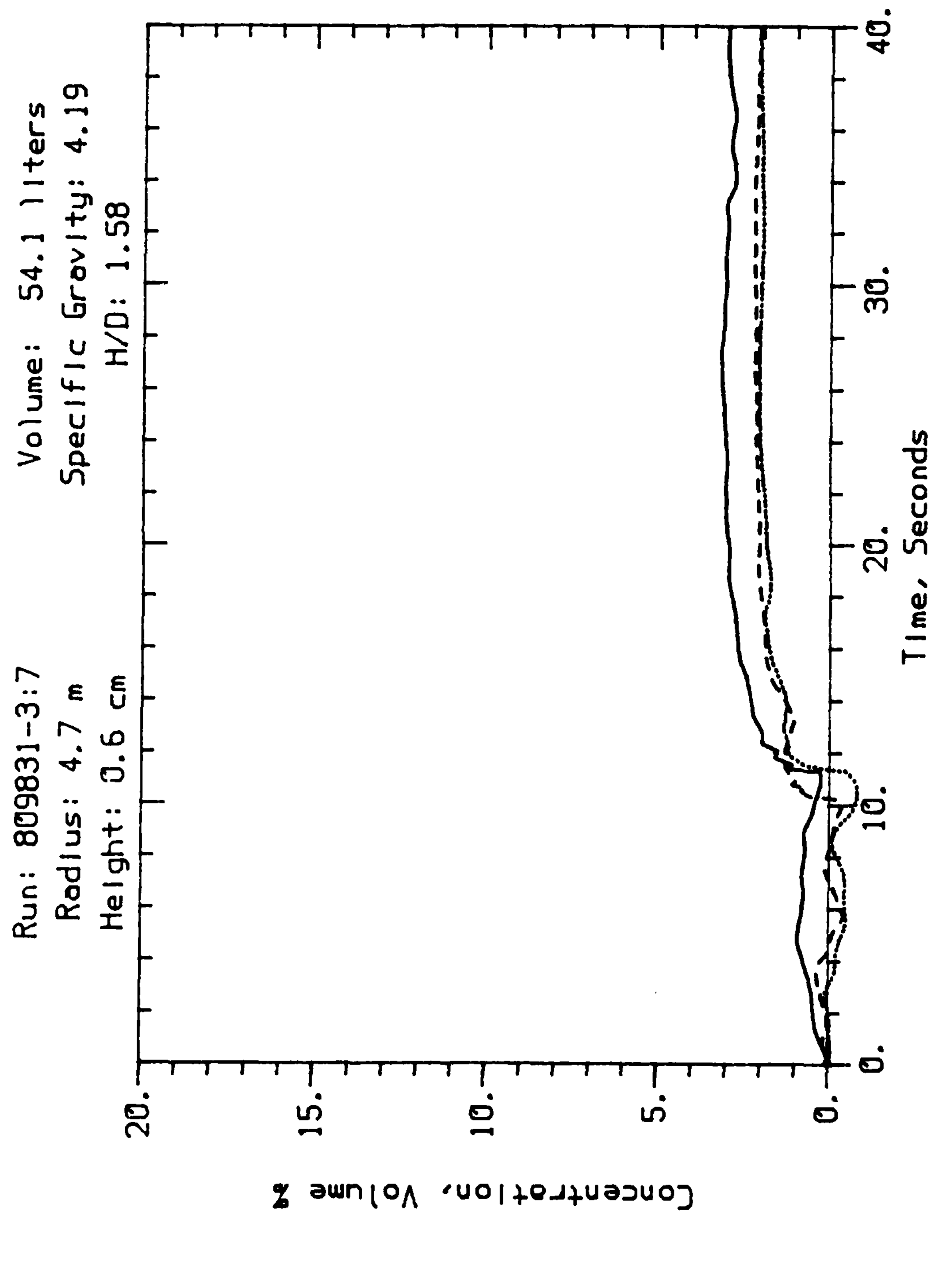


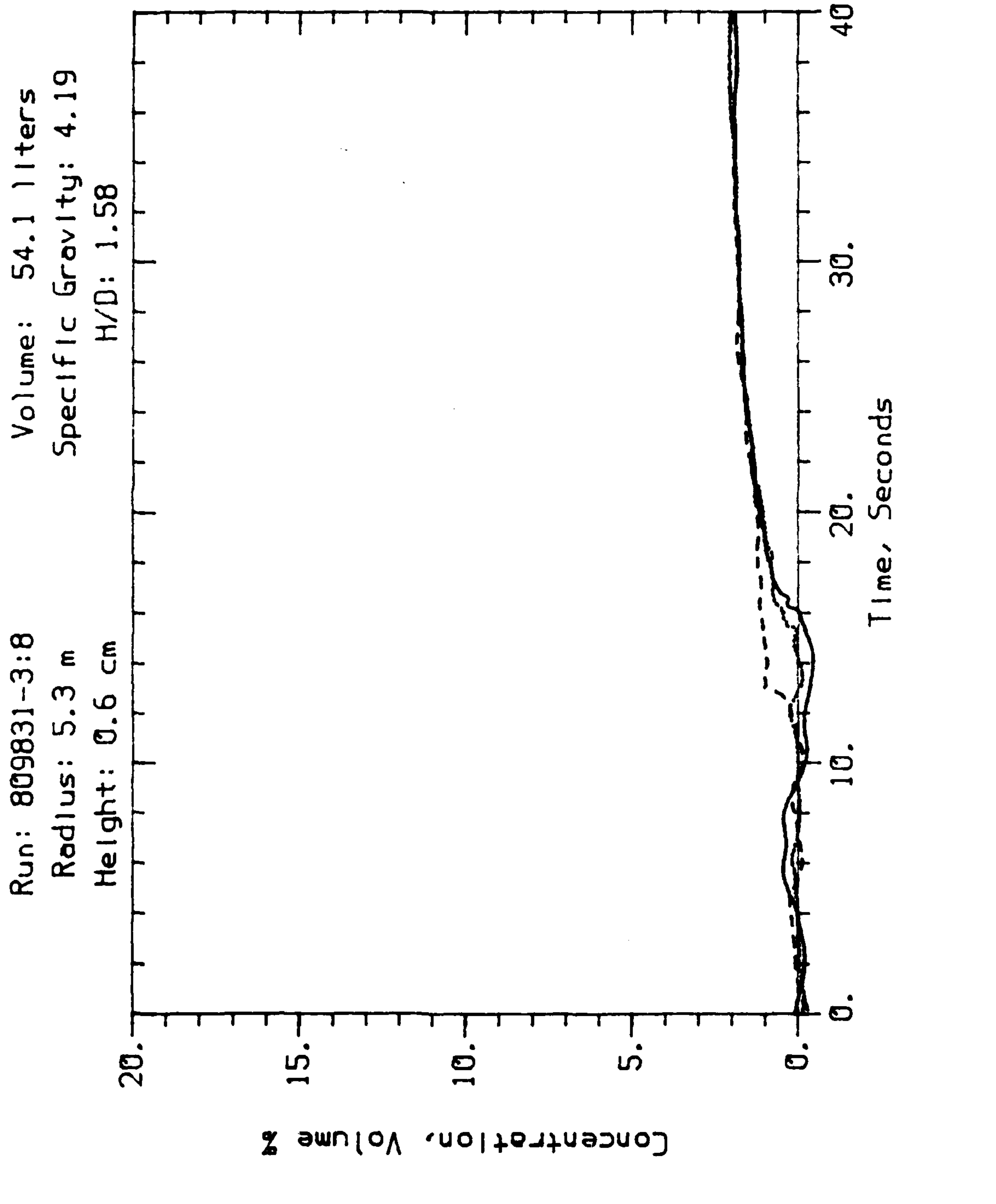
Run: 809831-3;4
Radius: 2.9 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
20.
15.
10.
5.
0.
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

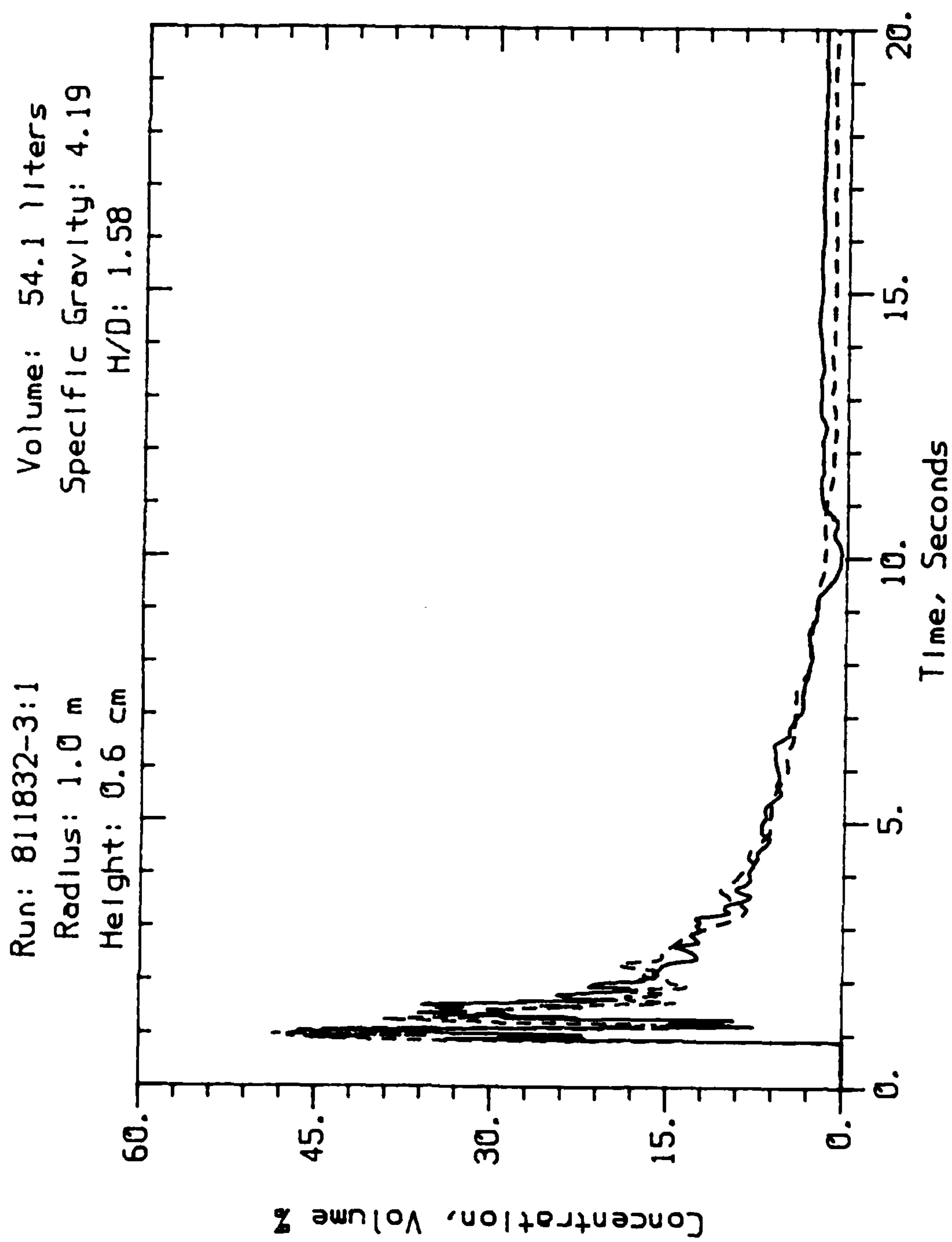

Run: 809831-3.5
Radius: 3.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
10.
20.
30.
40.

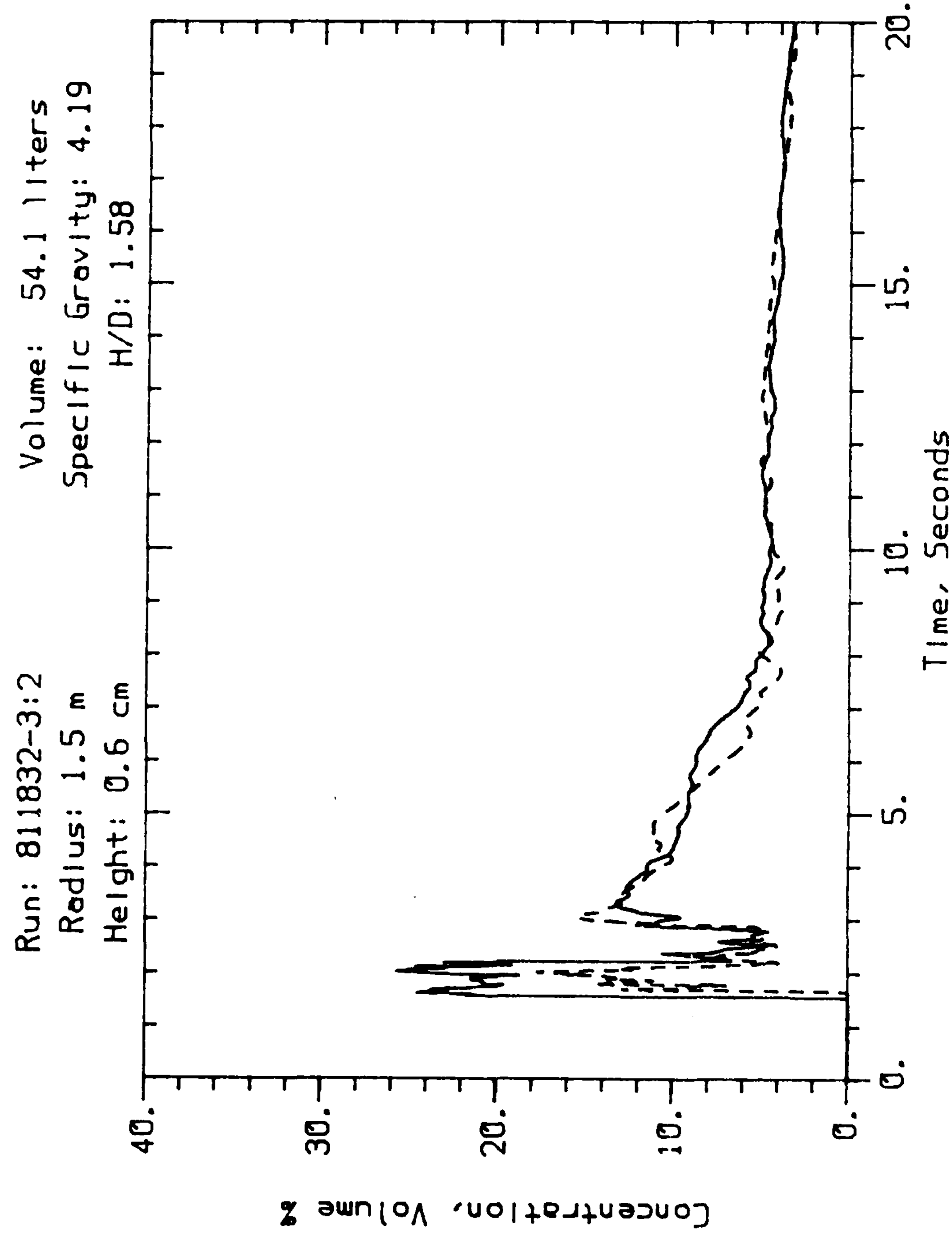


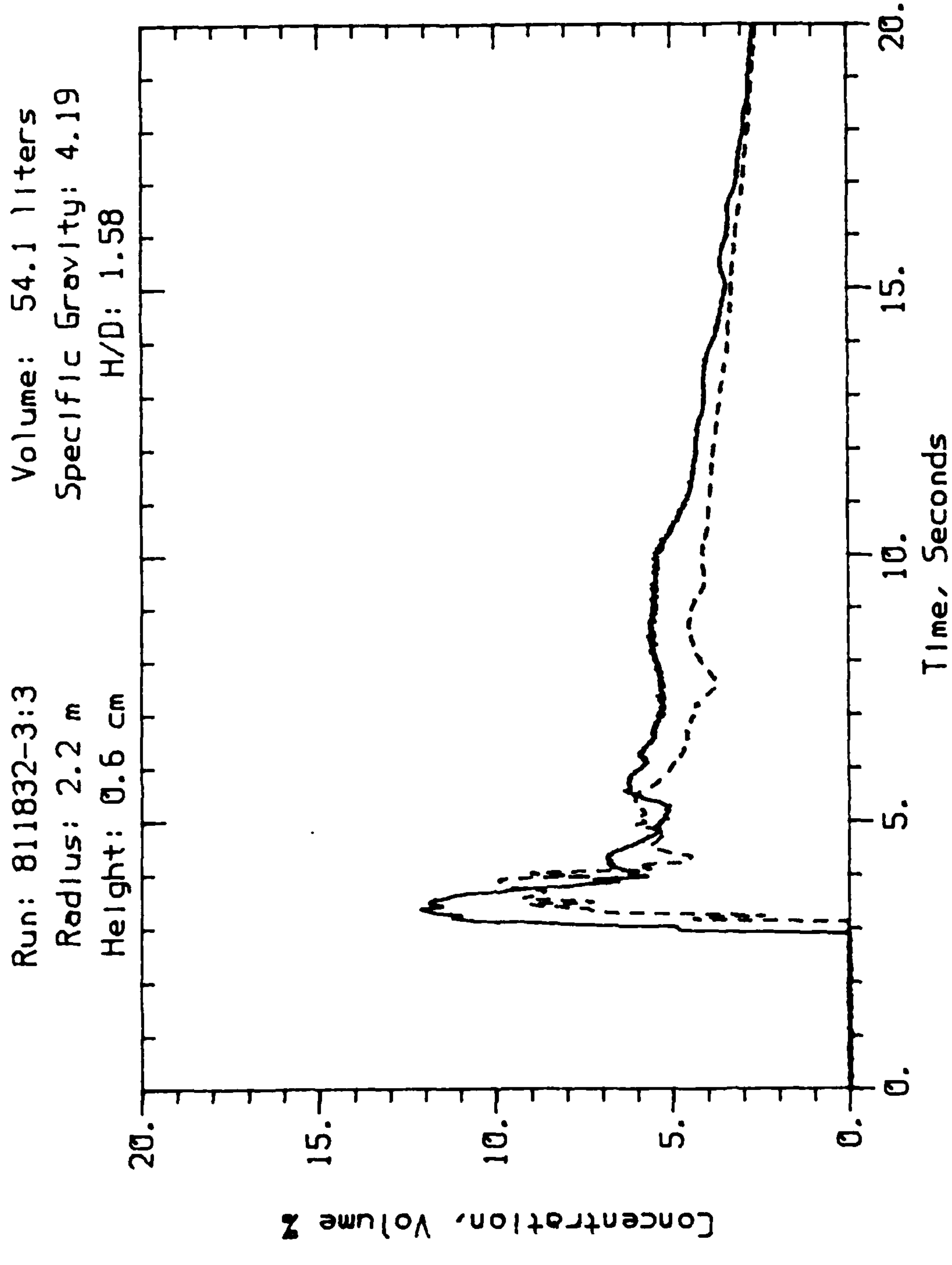
Run: 809831-3:6
Radius: 4.1 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
20.
15.
10.
5.
0.
0.
10.
20.
30.
40.
Time, Seconds

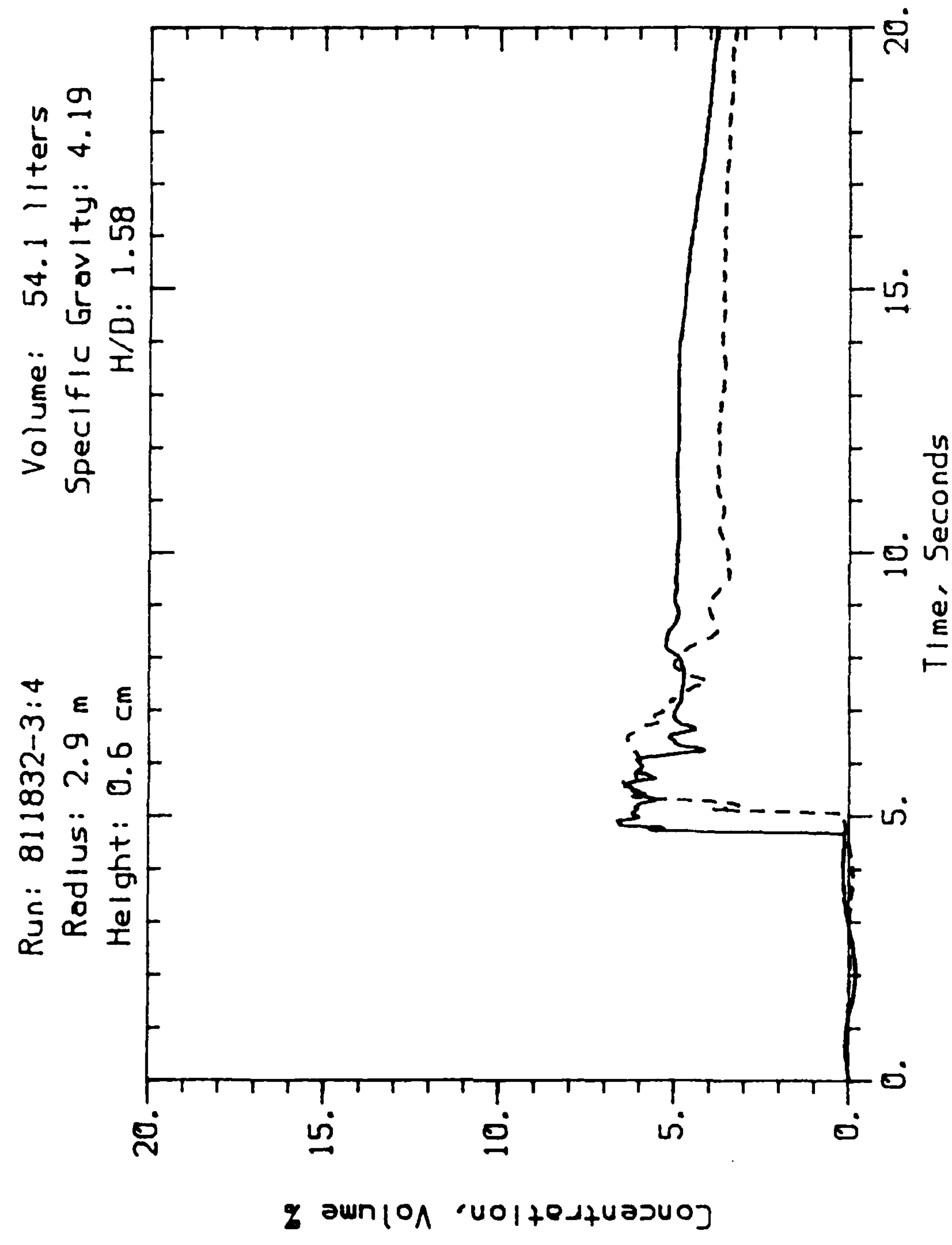

Run: 809831-3:7
Radius: 4.7 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
20.
15.
10.
5.
0.
Time, Seconds
0.
10.
20.
30.
40.


Run: 809831-3:8
Radius: 5.3 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.
0.
10.
20.
30.
40.

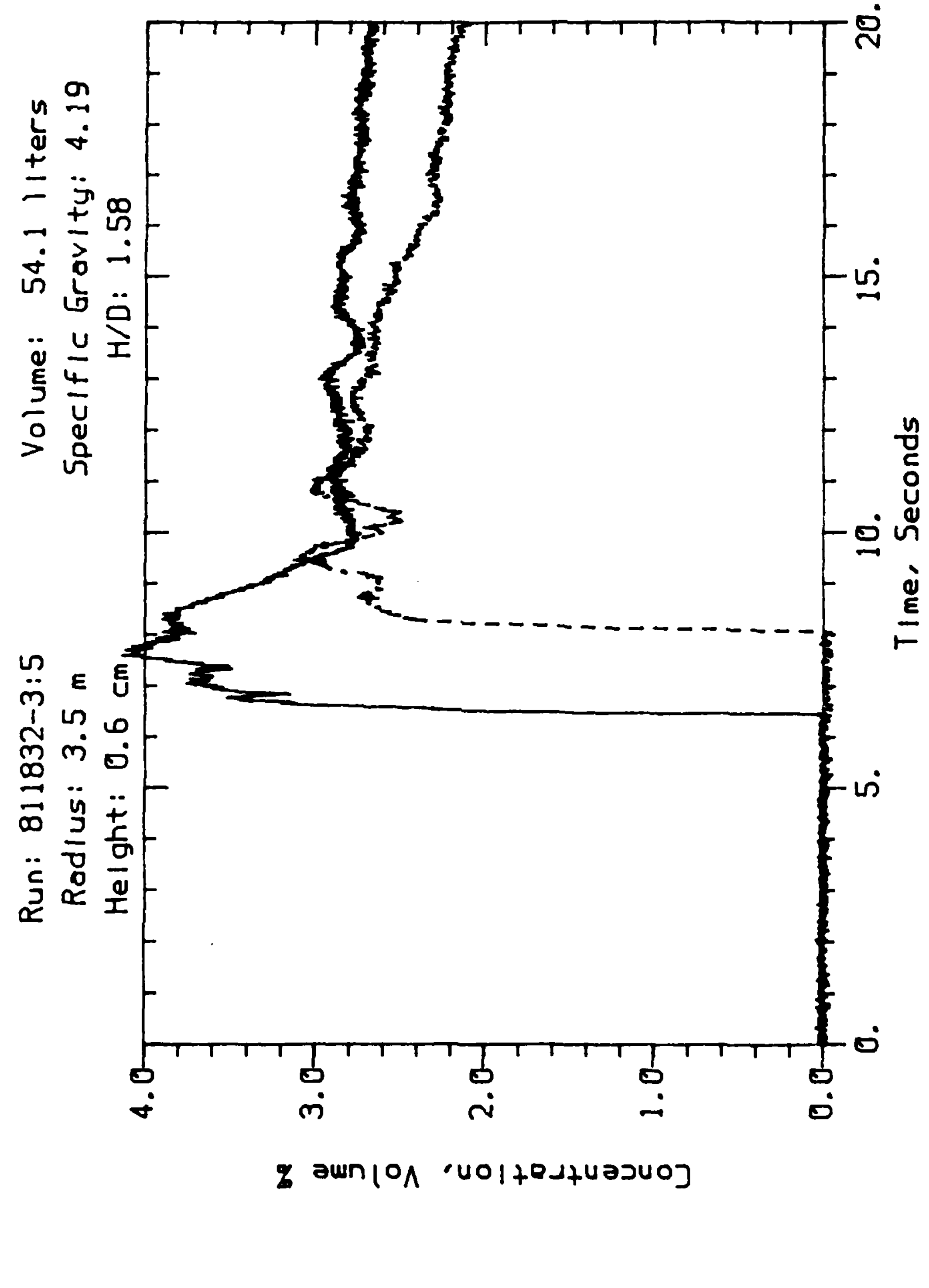

Run: 811832-3:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
60.
45.
30.
15.
0.
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

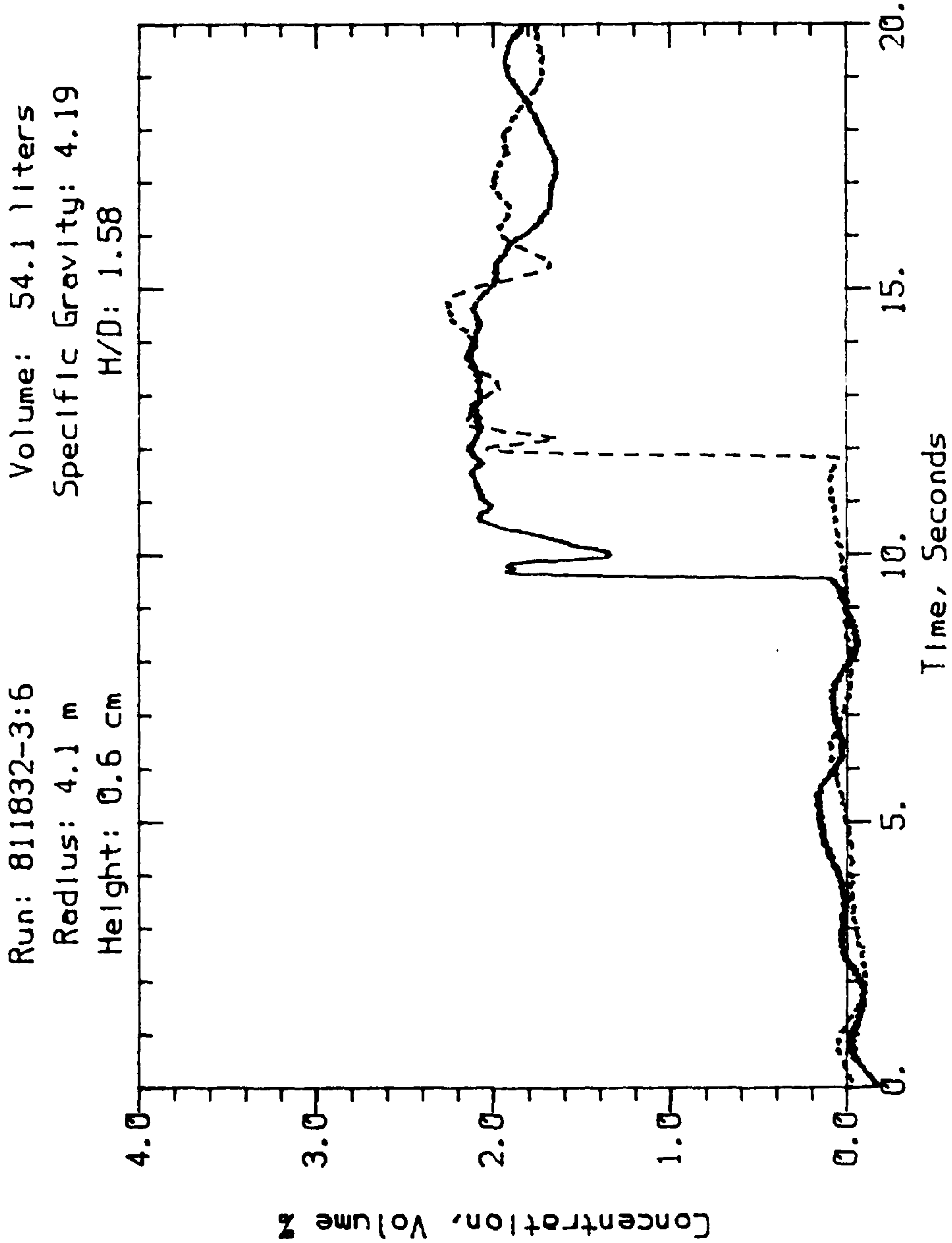

Run: 811832-3:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
0.
10.
20.
30.
40.
Time, Seconds
0.
5.
10.
15.
20.

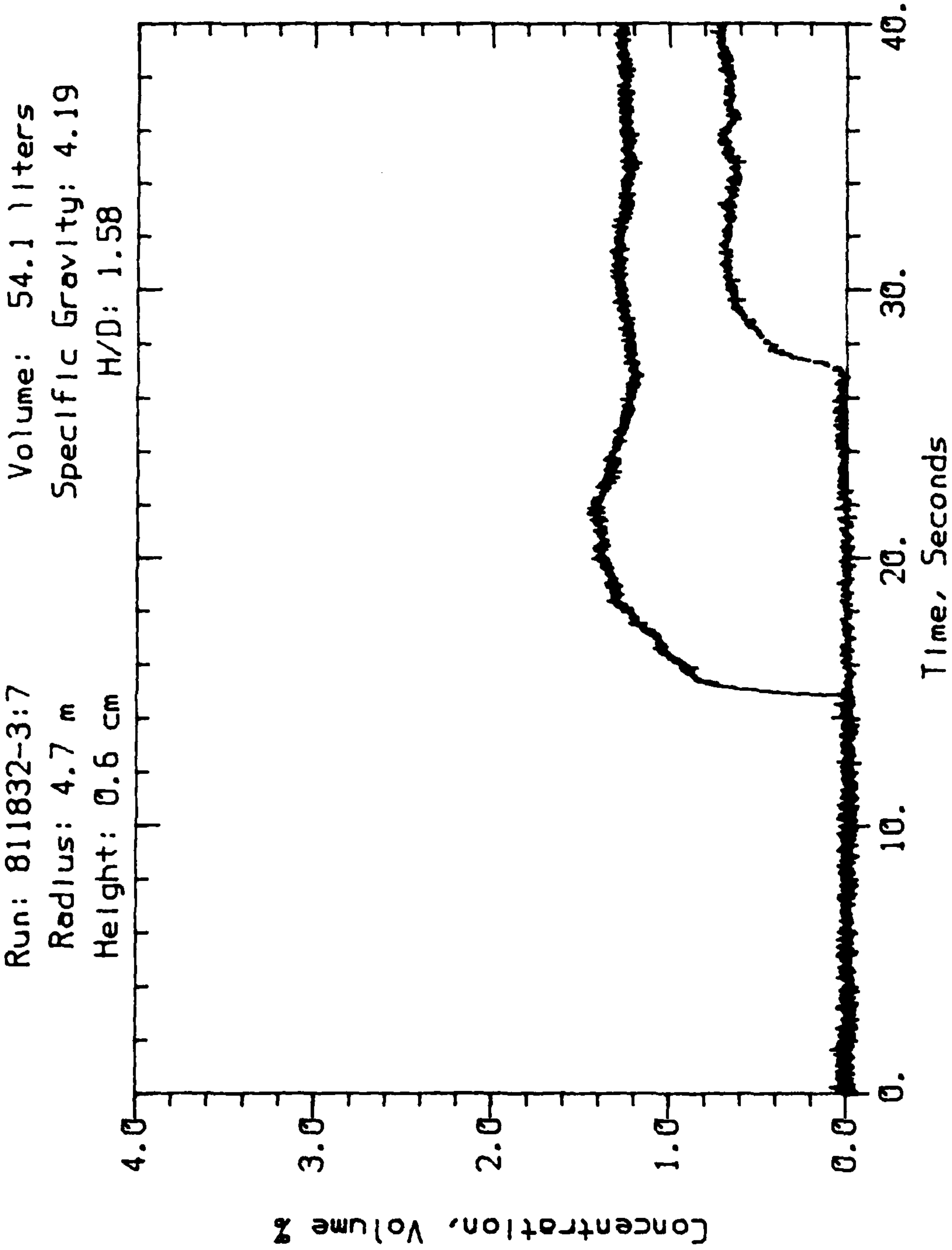

Run: 811832-3:3
Radius: 2.2 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Time, Seconds
Concentration, Volume %
0.
5.
10.
15.
20.

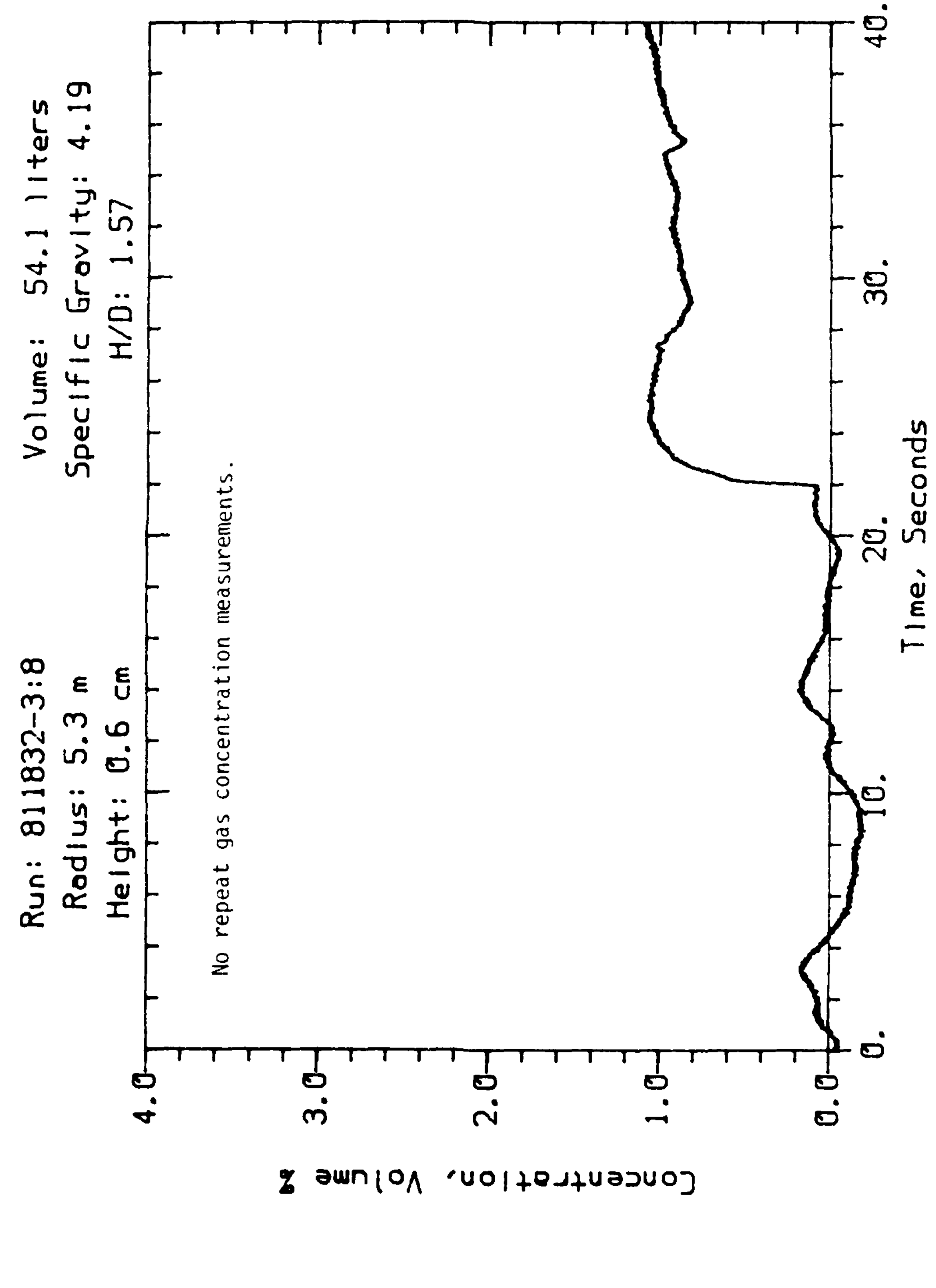


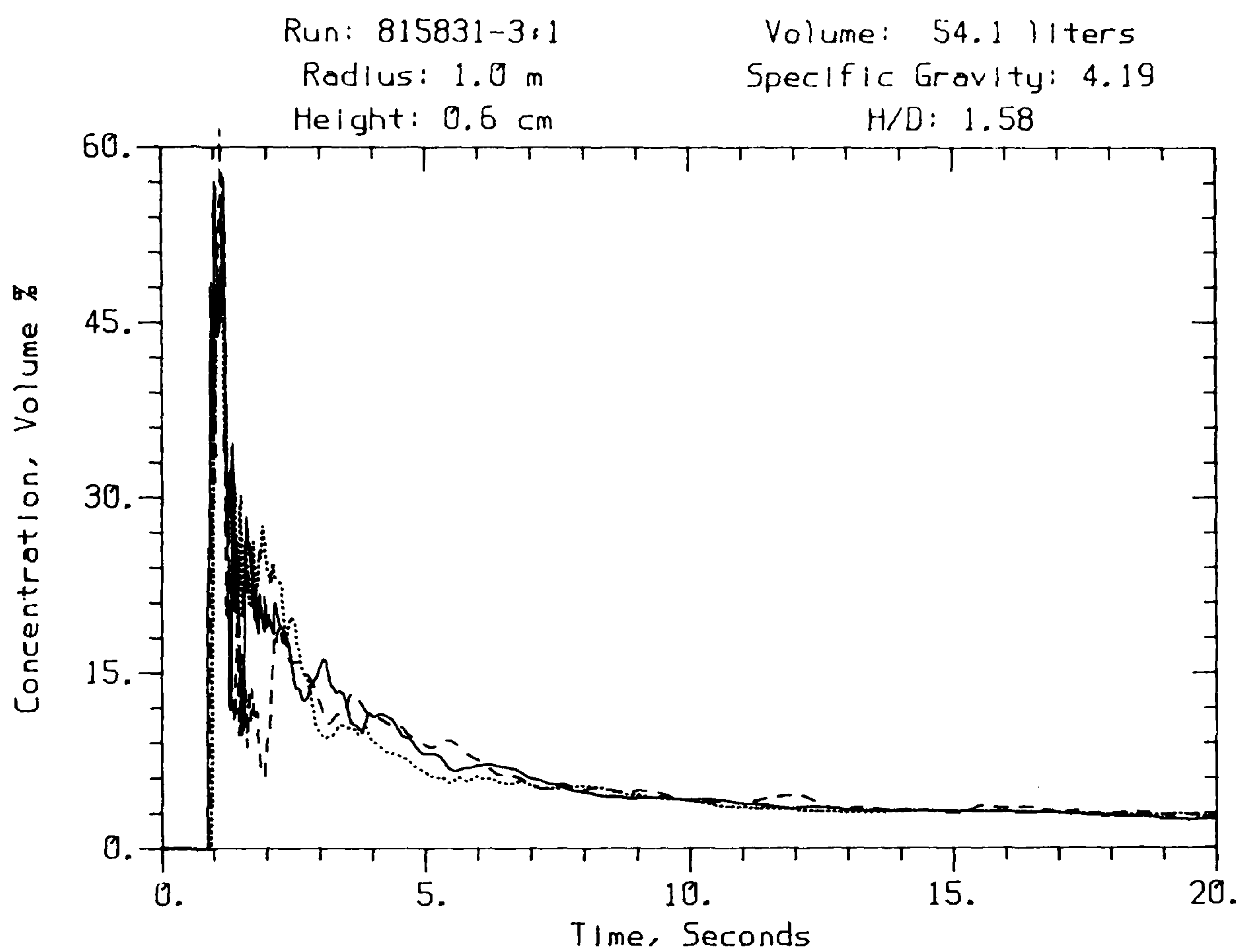
Run: 811832-3:4
Radius: 2.9 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

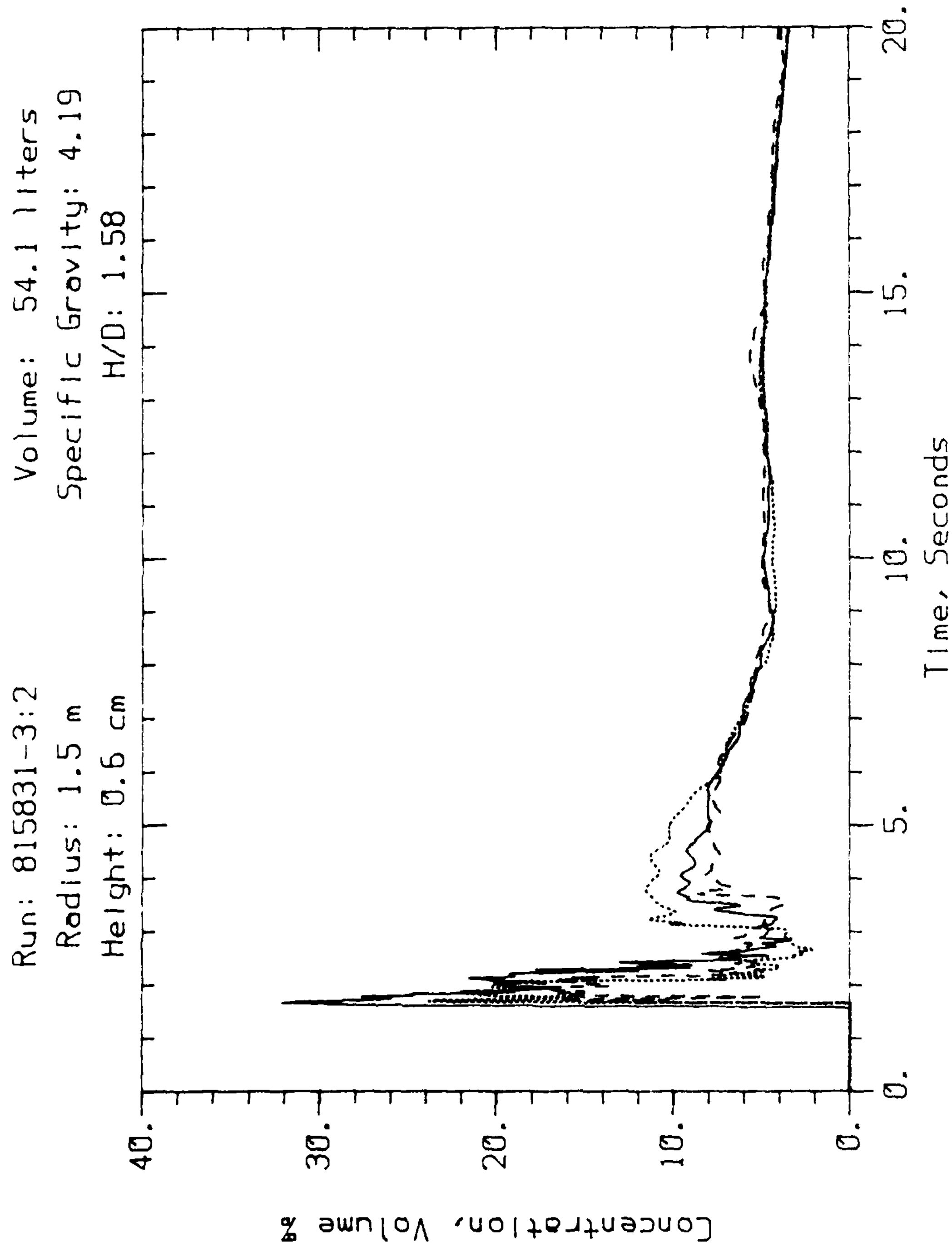

Run: 811832-3:5
Radius: 3.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
5.
10.
15.
20.

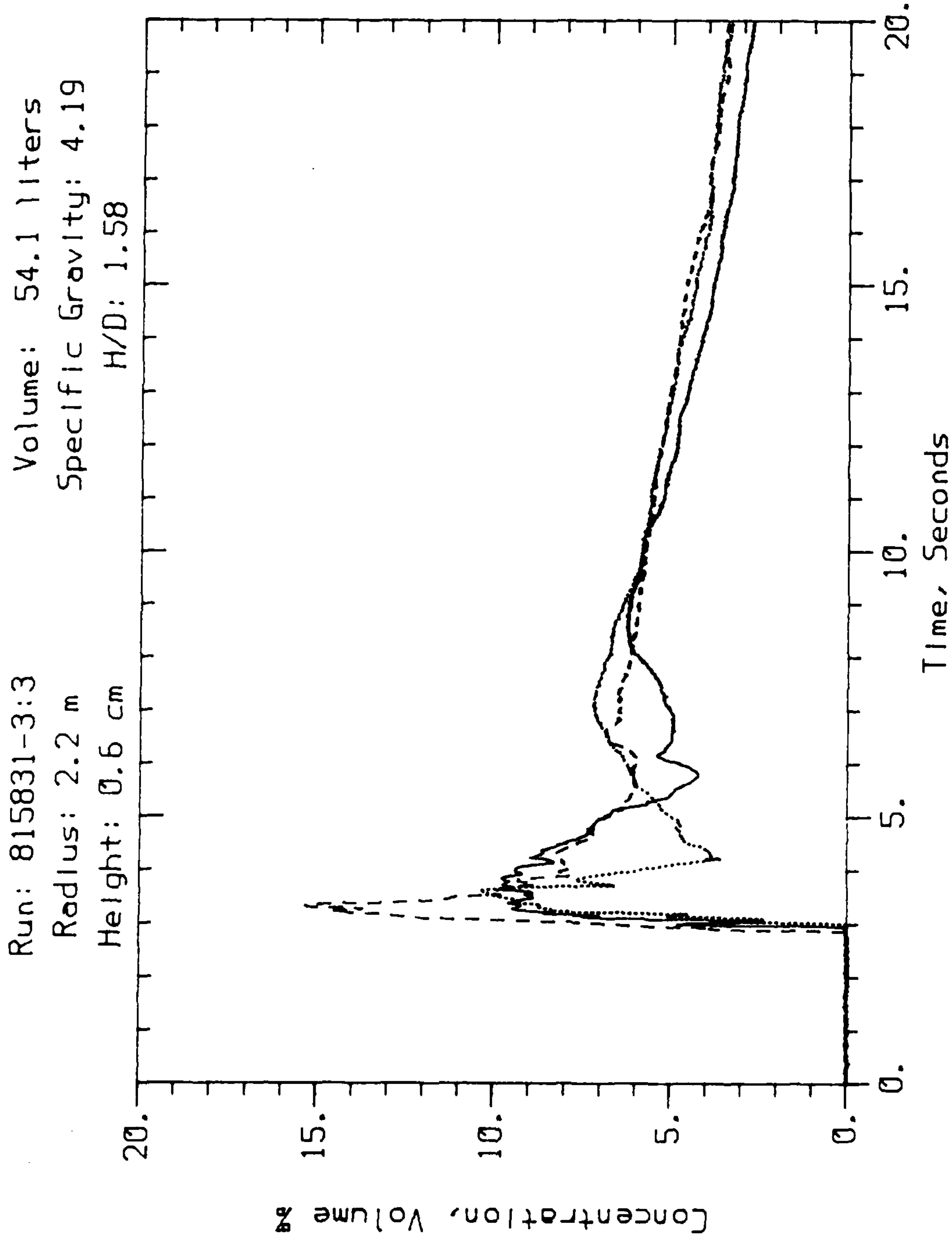

Run: 811832-3:6
Radius: 4.1 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
4.0
3.0
2.0
1.0
0.0
Time, Seconds
0.
5.
10.
15.
20.

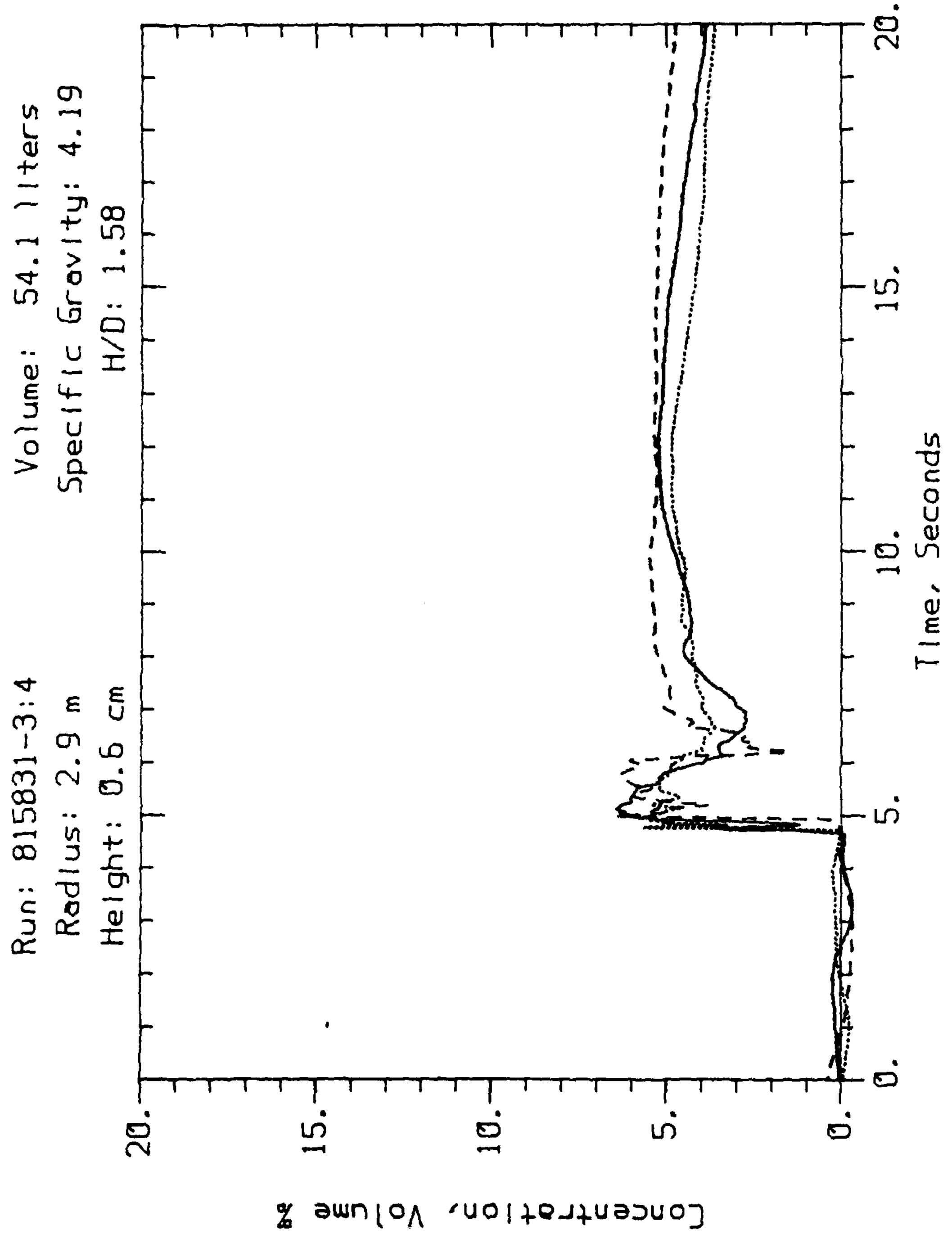

Run: 811832-3:7
Radius: 4.7 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
0.
10.
20.
30.
40.
Time, Seconds


Run: 811832-3:8
Radius: 5.3 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.57
No repeat gas concentration measurements.
Concentration, Volume %
4.0
3.0
2.0
1.0
0.0
0.
10.
20.
30.
40.
Time, Seconds

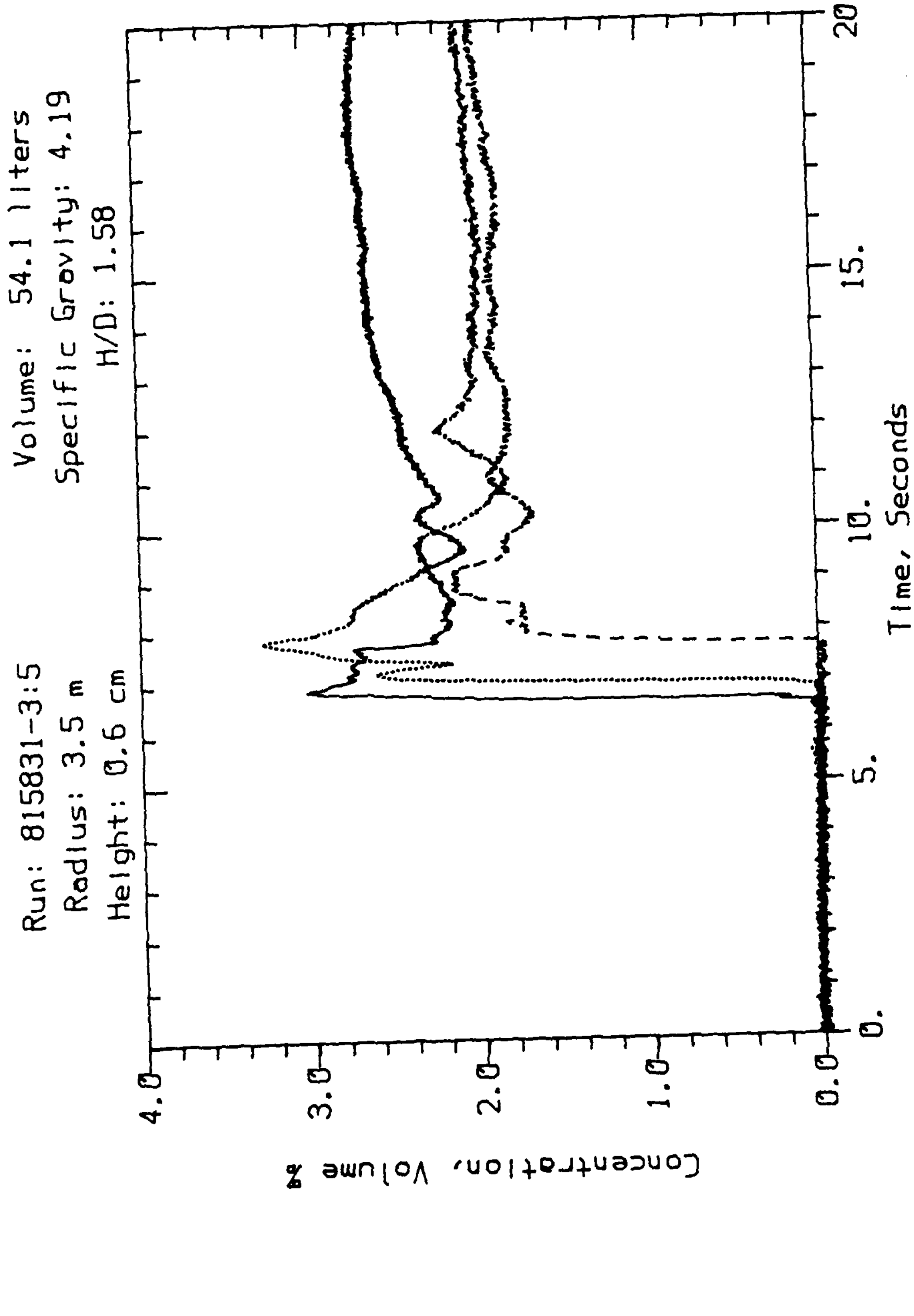

Run: 815831-3:1
Radius: 1.0 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
60.
45.
30.
15.
0.
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds

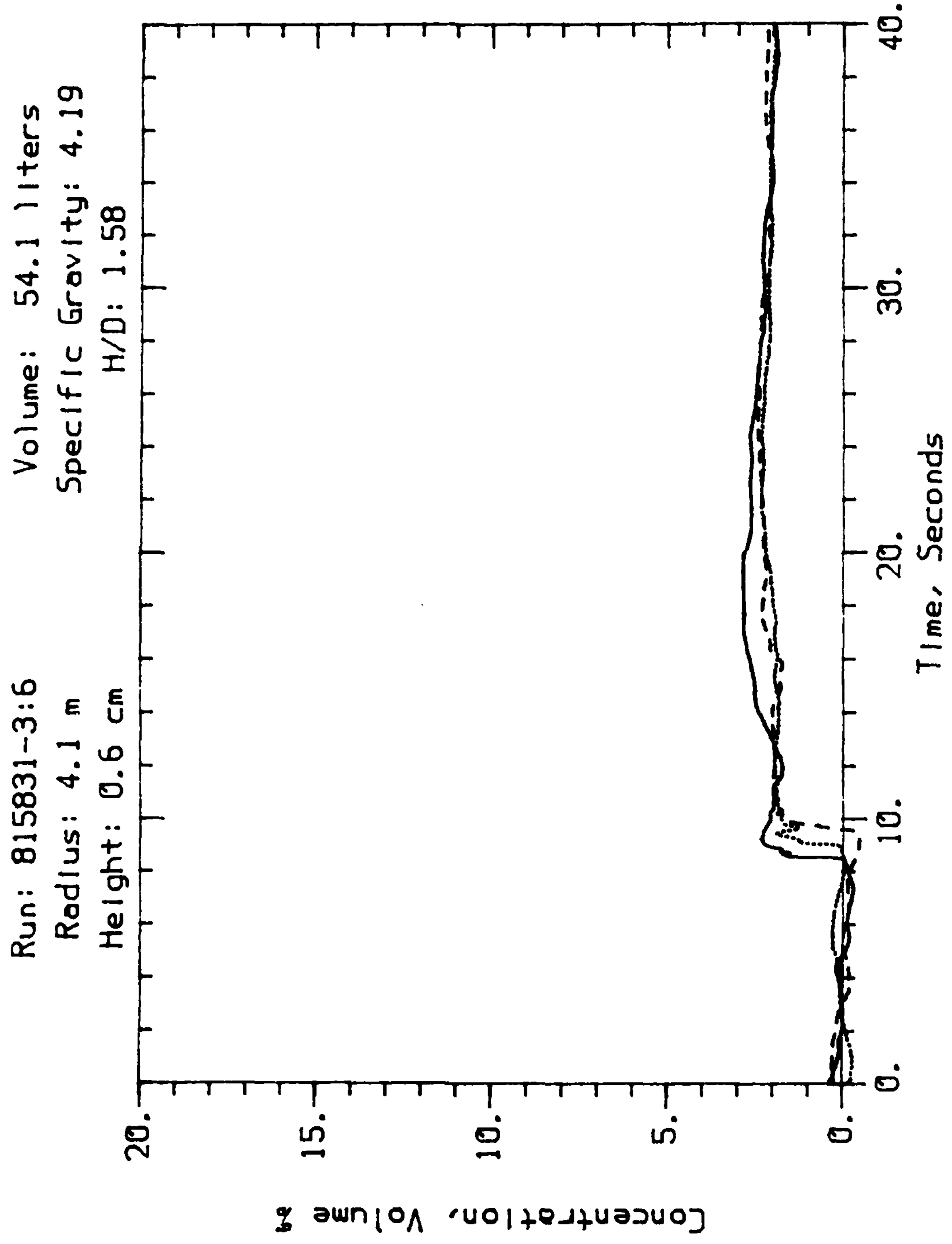

Run: 815831-3:2
Radius: 1.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
40.
30.
20.
10.
0.
0.
5.
10.
15.
20.
Time, Seconds


Run: 815831-3:3
Radius: 2.2 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

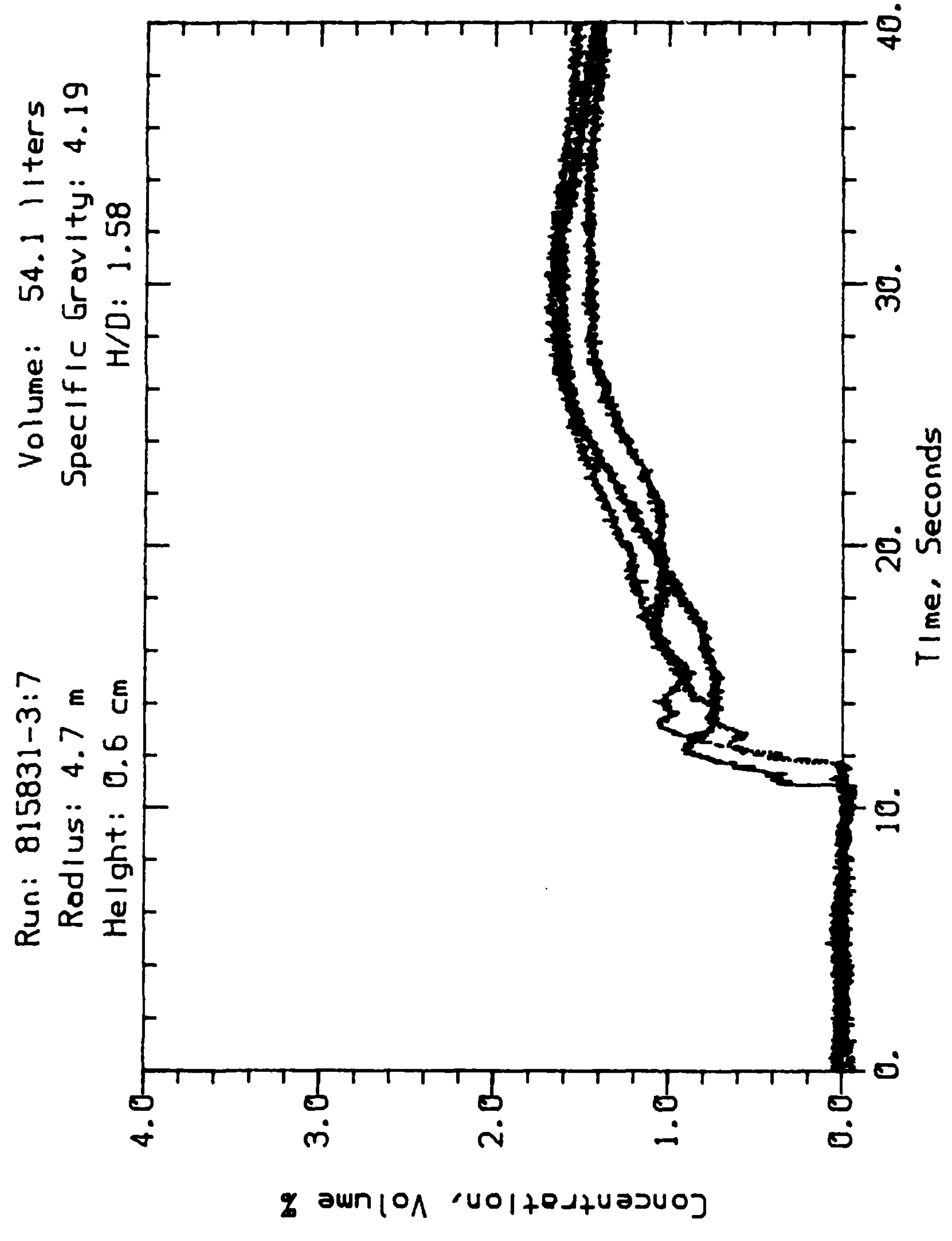


Run: 815831-3:4
Radius: 2.9 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
Time, Seconds
0.
5.
10.
15.
20.

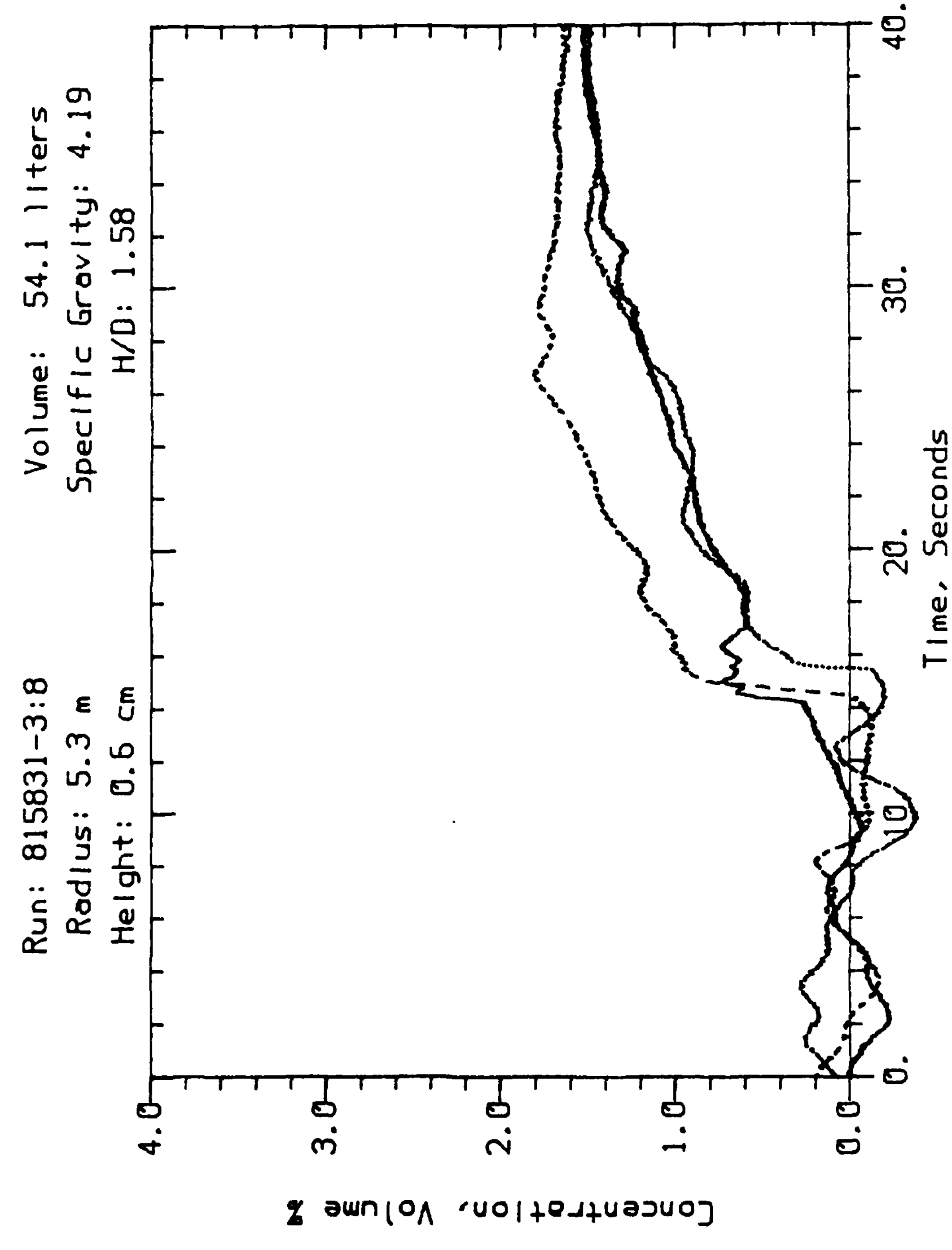

Run: 815831-3:5
Radius: 3.5 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
Time, Seconds
4.0
3.0
2.0
1.0
0.0
0.
5.
10.
15.
20.



Run: 815831-3:6
Radius: 4.1 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
0.
5.
10.
15.
20.
Time, Seconds
0.
10.
20.
30.
40.



Run: 815831-3:7
Radius: 4.7 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
0.
10.
20.
30.
40.
Time, Seconds
0.0
1.0
2.0
3.0
4.0
Concentration, Volume %



Run: 815831-3:8
Radius: 5.3 m
Height: 0.6 cm
Volume: 54.1 liters
Specific Gravity: 4.19
H/D: 1.58
Concentration, Volume %
0.0
1.0
2.0
3.0
4.0
Time, Seconds
0.
10
20.
30.
40.

APPENDIX B

EXPERIMENTAL DATA SUMMARIES

A summary of some experimental results for each experiment, in chronological order, follows. For each series of experiments, the following information is summarized for each channel:

(*) Experimental initial conditions

(*) Ambient conditions

(*) Gas sensor position (dimensional and nondimensional)

(*) Cloud time of arrival (TOA) based on the onset of measured concentration (dimensional and nondimensional)

(*) Maximum observed mole fraction (PEAK)

(*) Time of PEAK (TOP) (dimensional and nondimensional)

Experiment: 705830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	3.1/.019	1.33 1.24 1.31	9.91	.389 .424 .301	.371	1.39 1.44 1.59	11.3
2	1.5/0.6	4.6/.019	2.58 2.51 2.48	19.3	.174 .207 .202	.194	2.64 2.58 2.51	19.7
3	2.0/0.6	6.2/.019	4.38 4.23 3.99	32.2	.073 .081 .115	.090	5.1 4.77 4.06	35.6
4	2.5/0.6	7.7/.019	7.11 6.62 6.73	52.3	.036 .040 .042	.039	9.9 7.4 7.4	63.1
5	3.0/0.6	9.3/.019	11.2 9.42 9.92	78.0	.014 .020 .020	.018	27.0 12.0 24.8	163
6	3.5/0.6	10.8/.019	16.6 15.2 14.2	118	.010 .014 .014	.012	35.5 43.5 36.3	295

Initial Volume (l): 34.2
Initial Relative Density: 2.91
Initial $(H/D)_i$: 1.0
Temperature (°C): 28.0
Pressure (mm Hg): 736.6
Relative Humidity: 46%

$V_i^{1/3}$ (m) = .324

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.132

Experiment: 719830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	2.6/.016	1.04 1.07	7.49	.612 .585	.599	1.11 1.18	8.13
2	1.5/0.6	4.0/.016	1.99 2.00	14.2	.232 .199	.216	2.28 2.40	16.6
3	2.0/0.6	5.3/.016	3.03 3.21	22.2	.178 .105	.142	3.08 4.09	25.5
4	2.5/0.6	6.6/.016	4.77 4.60	33.2	.075 .088	.081	5.46 5.45	38.7
5	3.0/0.6	7.9/.016	7.05 7.01	49.9	.038 .035	.037	7.94 8.25	57.5
6	3.5/0.6	9.3/.016	9.37 9.82	68.1	.026 .022	.024	23.8 19.3	153
7	4.0/0.6	10.6/.016	11.6 NR	--	.025 .012	.019	28.7 40.5	246

Initial Volume (l): 54.1
Initial Relative Density: 2.91
Initial $(H/D)_i$: 1.0
Temperature (^{o}C): 28.4
Pressure (mm Hg): 736.0
Relative Humidity: 54%

$V_i^{1/3}$ (m) = .375

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.142

Experiment: 728830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	3.1/.019	1.53 1.70	9.67	.438 .334	.386	1.65 1.78	10.3
2	1.5/0.6	4.6/.019	3.33 3.32	19.9	.162 .135	.149	4.29 3.68	23.9
3	2.0/0.6	6.2/.019	5.69 5.22	32.7	.083 .082	.082	6.44 5.79	36.6
4	2.5/0.6	7.7/.019	NR NR	--	-- --	--	--	--
5	3.0/0.6	9.3/.019	21.8 19.7	124	.014 --		25.8 --	--
6	3.5/0.6	10.8/.019	NR 28.2	169	-- --		50.1	300
7	4.0/0.6	12.3/.019	NR 47.6	285.0	-- --		49.9	299
8	4.5/0.6	13.9/.019	NR NR	--	-- --	--	--	--

Initial Volume (l): 34.2
Initial Relative Density: 2.16
Initial $(H/D)_i$: 1.0
Temperature (^{o}C): 34.5
Pressure (mm Hg): 734.4
Relative Humidity: 43%

$V_i^{1/3}$ (m) = .324

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.169

Experiment: 802830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	1.9/.011	0.80 0.83	4.97	.933 .897	.915	.99 .98	6.01
2	1.5/0.6	2.9/.011	1.38 1.36	8.36	.757 .511	.634	1.58 1.65	9.85
3	2.3/0.6	4.3/.011	2.48 2.70	15.8	.299 .213	.256	2.49 2.91	16.5
4	3.2/0.6	5.95/.011	4.61 4.75	28.5	.128 .125	.127	4.67 5.11	29.8
5	4.05/0.6	7.53/.011	7.65 7.52	46.3	.058 .049	.054	8.3	
6	4.7/0.6	8.7/.011	10.8 9.57	62.1	.043 .040	.041	24.6 15.8	123
7	5.5/0.6	10.2/.011	17.0 13.3	92.4	.030 .031	.030	37.6 32.2	213
8	6.3/0.6	11.7/.011	23.5 21.0	136	.025 .028	.027	60.1 69.7	396

Initial Volume (l): 135
Initial Relative Density: 2.91
Initial $(H/D)_i$: 1.0
Temperature (^oC): 30.7
Pressure (mm Hg): 736.9
Relative Humidity: 54%

$V_i^{1/3}$ (m) = .513

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.165

Experiment: 805830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	1.9/.011	0.70 0.74	5.66	.932 .935	.934	1.01 0.97	7.78
2	1.5/0.6	2.92/.011	1.13 1.18	9.08	.623 .598	.611	1.37 1.36	10.7
3	2.3/0.6	4.3/.011	2.10 2.30	17.3	.276 .170	.223	2.26 2.80	19.9
4	3.2/0.6	5.95/.011	4.15 3.78	31.2	.087 .119	.103	4.56 3.82	32.9
5	4.05/0.6	7.53/.011	6.20 5.67	46.6	.079 .066	.072	7.73 5.91	53.6
6	4.7/0.6	8.7/.011	8.83 7.70	64.9	.034 .051	.042	15.1 21.2	143
7	5.5/0.6	10.2/.011	13.0 10.5	92.3	.020 .038	.029	37.5 27.3	255
8	6.3/0.6	11.7/.011	18.6 14.4	130	.0150 .027	.021	60.0 32.1	362

Initial Volume (l): 135
Initial Relative Density: 4.19
Initial (H/D)$_i$: 1.0
Temperature (°C): 31.0
Pressure (mm Hg): 735.8
Relative Humidity: 46%

$V_i^{1/3}$ (m) = .513

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.128

Experiment: 807830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	1.9/.011	1.02 1.03 1.00	4.84	.746 .779 .795	.773	1.19 1.14 1.06	5.38
2	1.5/0.6	2.9/.011	1.83 1.82 1.83	8.69	.409 .453 .403	.422	2.11 1.84 1.93	9.33
3	2.3/0.6	4.5/.011	3.53 3.71 3.61	17.2	.154 .113 .177	.148	3.77 3.73 .400	18.2
4	3.2/0.6	6.2/.011	6.45 6.19 6.06	29.67	.094 .125 .109	.109	7.18 6.26 6.30	31.3
5	4.05/0.6	7.9/.011	9.42 9.32 9.52	44.8	.055 .058 .061	.058	17.0 9.57 21.4	76.1
6	4.7/0.6	9.2/.011	11.7 12.8 13.0	59.5	.042 .050 .049	.047	33.3 44.1 52.0	205
7	5.5/0.6	10.7/.011	16.3 16.6 15.5	76.6	.030 -- .047	.038	37.5 -- 56.9	225
8	6.3/0.6	12.3/.011	19.9 22.2 NR	100	.023 -- .042	.033	43.7 -- 47.1	216

Initial Volume (l): 135
Initial Relative Density: 2.16
Initial $(H/D)_o$: 1.0
Temperature (^oC): 30.4
Pressure (mm Hg): 735.2
Relative Humidity: 55%

$V_i^{1/3}$ (m) = .513

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.212

Experiment: 808830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	2.65/.016	0.83 0.92 0.84	7.87	.719 .622 .750	.697	1.04 1.11 1.01	9.61
2	1.5/0.6	3.97/.016	1.45 1.49 1.43	13.4	.489 .440 .479	.469	1.96 2.28 2.19	19.6
3	2.2/0.6	5.82/.016	2.60 2.81 2.62	24.5	.213 .170 .203	.195	2.94 4.81 2.71	31.9
4	2.9/0.6	7.67/.016	4.18 4.75 4.46	40.9	.106 .073 .093	.090	8.06 9.08 7.52	75.3
5	3.5/0.6	9.26/.016	6.03 7.00 6.83	60.6	.053 .040 .048	.047	11.3 20.5 14.0	140
6	4.1/0.6	10.8/.016	8.02 9.57 NR	80.5	.036 .030 --	.033	18.9 28.1 --	215
7	4.7/0.6	12.4/.016	10.6 NR 13.5	110	.023 -- .032	.028	33.6 -- 35.4	316
8	5.3/0.6	14.0/.016	NR NR NR	--	-- -- --	--	-- -- --	--

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial $(H/D)_i$: 0.4
Temperature (°C): 26.9
Pressure (mm Hg): 733.2
Relative Humidity: 58%

$V_i^{1/3}$ (m) = .378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

Experiment: 809830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	2.65/.016	0.94 0.91 0.90	8.4	.541 .600 .602	.581	1.09 1.01 0.97	9.37
2	1.5/0.6	3.97/.016	1.50 1.62 1.55	14.3	.313 .307 .207	.276	1.71 1.80 1.83	16.3
3	2.2/0.6	5.82/.016	3.10 3.02 2.78	27.2	.098 .085 .152	.112	3.45 3.16 2.82	28.8
4	2.9/0.6	7.67/.016	4.55 4.89 4.65	43.0	.086 .058 .064	.069	4.71 5.96 4.92	47.6
5	3.5/0.6	9.26/.016	6.32 6.43 6.34	58.3	.036 .037 .034	.036	15.5 8.14 7.36	94.7
6	4.1/0.6	10.8/.016	9.12 8.03 8.60	78.6	.031 .033 .024	.030	22.4 17.0 20.8	184
7	4.7/0.6	12.4/.016	11.0 10.1 11.0	98.0	.027 .022 .024	.0243	27.4 33.3 39.1	305
8	5.3/0.6	14.0/.016	NR 12.5 NR	--	-- .0207 --	--	-- 37.6 --	--

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial $(H/D)_i$: 1.57
Temperature (°C): 27.2
Pressure (mm Hg): 733.6
Relative Humidity: 60%

$V_i^{1/3}$ (m) = .378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

Experiment: 811830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	2.65/.016	.90 .89	8.21	.441 .488	.465	1.09 1.01	9.63
2	1.5/0.6	3.97/.016	1.58 1.69	15.0	.258 .180	.219	2.05 2.03	18.7
3	2.2/0.6	5.82/.016	2.94 3.16	28.0	.121 .100	.110	3.38 3.94	33.4
4	2.9/0.6	7.67/.016	4.71 5.10	45.0	.066 .065	.065	4.93 5.66	48.6
5	3.5/0.6	9.26/.016	6.50 8.12	67.1	.041 .031	.036	7.65 9.52	78.8
6	4.1/0.6	10.8/.016	9.59 11.9	98.6	.021 .023	.022	13.8 14.7	131
7	4.7/0.6	12.4/.016	15.0 27.3	194	.015 .008	.012	21.8 44.6	305
8	5.3/0.6	14.0/.016	22.1 NR	--	.012 --	--	43.1 --	--

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial (H/D)$_i$: 1.57
Temperature (^oC): 28.9
Pressure (mm Hg): 733.3
Relative Humidity: 78%

$V_i^{1/3}$ (m) = .378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

Experiment: 815830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	2.65/.016	0.88 0.92 0.96	8.42	.575 .618 .500	.564	1.21 1.14 1.19	10.8
2	1.5/0.6	3.97/.016	1.60 1.69 1.69	15.2	.321 .175 .237	.244	1.69 1.95 1.71	16.3
3	2.2/0.6	5.82/.016	2.98 2.90 3.05	27.3	.098 .153 .104	.118	3.87 3.36 3.64	33.2
4	2.9/0.6	7.67/.016	4.70 4.96 4.76	44.0	.064 .064 .057	.062	5.13 5.00 4.79	45.5
5	3.5/0.6	9.26/.016	6.60 7.75 6.94	65.0	.030 .022 .033	.028	6.90 8.88 7.87	72.2
6	4.1/0.6	10.8/.016	8.54 9.42 8.92	82.0	.029 .025 .024	.026	19.3 25.0 21.8	202
7	4.7/0.6	12.4/.016	10.9 11.6 11.5	104.0	.017 .028 .015	.017	31.7 30.3 31.6	286
8	5.3/0.6	14.0/.016	14.4 14.4 15.3	135.0	.015 .018 .017	.017	39.7 26.8 49.8	355

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial $(H/D)_i$: 1.58
Temperature (^oC): 28.9
Pressure (mm Hg): 734.7
Relative Humidity: 54%

$V_i^{1/3}$ (m) = .378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

Experiment: 815834

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	2.65/.016	0.87 0.89 0.90	8.15	.650 .740 .628	.673	0.92 1.04 1.09	9.34
2	1.5/0.6	3.97/.016	1.50 1.76 1.63	14.9	.272 .285 .249	.269	2.38 2.27 1.82	19.7
3	2.2/0.6	5.82/.016	2.94 3.12 3.16	28.1	.106 .116 .075	.099	3.51 3.87 3.69	33.8
4	2.9/0.6	7.67/.016	4.80 5.02 4.86	48.9	.070 .062 .059	.064	5.69 9.95 4.99	62.9
5	3.5/0.6	9.26/.016	6.77 7.51 7.53	66.5	.026 .023 .024	.024	16.7 12.5 10.1	120
6	4.1/0.6	10.8/.016	9.02 11.2 10.6	94.0	.028 .020 .021	.029	24.2 30.4 14.7	211
7	4.7/0.6	12.4/.016	11.9 13.7 14.6	123	.017 .012 .011	.013	28.9 34.1 28.6	280
8	5.3/0.6	14.0/.016	14.6 NR NR	--	.018 .0095 .0066	.012	45.5 31.2 49.9	386

Initial Volume (l): 1.0
Initial Relative Density: 4.19
Initial (H/D): 1.0
Temperature (^{o}C): 28.7
Pressure (mm Hg): 734.7
Relative Humidity: 58%

$V_i^{1/3}$ (m) = .378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

Experiment: 817830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	3.09/.019	0.97 1.01 1.00	9.82	.416 .435 .410	.420	1.17 1.12 1.13	11.3
2	1.5/0.6	4.63/.019	1.95 1.90 1.90	18.9	.188 .166 .172	.175	2.19 2.20 2.06	21.3
3	2.0/0.6	6.17/.019	2.70 2.86 2.86	27.7	.119 .122 .116	.119	3.45 3.83 3.78	36.4
4	2.5/0.6	7.72/.019	4.40 4.61 4.51	44.5	.051 .050 .046	.049	4.46 4.92	46.4
5	3.0/0.6	9.26/.019	6.71 6.32 6.74	65.1	.023 .027 .021	.024	10.5 15.1 22.3	158
6	3.5/0.6	10.8/.019	9.08 8.46 9.52	89.2	.020 .026 .021	.022	12.2 19.6 25.9	190
7	4.0/0.6	12.3/.019	12.0 11.7 14.0	124	.015 .014 .012	.014	44.5 43.0 35.6	406
8	4.0/0.6	12.3/.019	12.0 13.7 14.1	131	.020 .015 .015	.017	45.2 42.4 47.2	444

Initial Volume (l): 34.2
Initial Relative Density: 4.19
Initial $(H/D)_i$: 1.0
Temperature (^oC): 28.3
Pressure (mm Hg): 734.4
Relative Humidity: 54%

$V_i^{1/3}$ (m) = .324

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.102

Experiment: B08830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.5/16.	4.0/0.423	1.26 2.78	18.5	0.0021 0.0006	--	2.95 --	--
2	1.5/0.6	4.0/0.016	1.56 1.59	14.4	0.426 0.304	.365	1.66 1.73	15.5
3	2.9/8.0	7.7/0.212	5.52 5.67	51.1	0.015 0.020	.017	6.07 5.87	54.5
4	2.9/0.6	7.7/0.016	5.08 5.40	47.9	0.060 0.053	.056	6.22 6.66	58.8
5	2.9/16.	7.7/0.423	NR NR	--	NR NR	--	--	--
6	4.1/8.0	10.8/0.212	13.3 12.9	120	0.0054 0.0072	.0063	14.7 13.1	127
7	4.1/0.6	10.8/0.016	12.8 12.7	116	0.015 0.014	.015	28.5 31.2	273
8	4.1/16.	10.8/0.423	NR NR	--	NR NR	--	--	--

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial $(H/D)_i$: 1.0
Temperature (^oC): 18.8
Pressure (mm Hg): 731.9
Relative Humidity: 62%

$V_i^{1/3}$ (m) = 0.378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

Experiment: B09830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.5/6.0	4.0/0.159	1.67 1.58	14.8	0.095 0.154	.125	1.83 1.64	15.9
2	1.5/0.6	4.0/0.016	1.52 1.52	13.9	0.401 0.308	.355	1.55 1.81	15.3
3	2.9/3.0	7.7/0.079	5.21 4.88	46.0	0.038 0.047	.042	5.68 4.90	48.3
4	2.9/0.6	7.7/0.016	5.25 4.94	46.5	0.069 0.060	.064	6.89 8.20	68.9
5	2.9/6.0	7.7/0.159	5.26 5.01	46.9	0.027 0.028	.028	5.62 5.10	49.0
6	4.1/3.0	10.8/0.079	NR 10.0		NR NR		NR NR	
7	4.1/0.6	10.8/0.016	NR 10.3		NR NR		NR NR	
8	4.1/6.0	10.8/0.0159	NR 10.3		NR NR		NR NR	

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial (H/D): 1.0
Temperature (°C): 18.0
Pressure (mm Hg): 730.0
Relative Humidity: 62%

$V_i^{1/3}$ (m) = 0.378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

Experiment: B11830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.5/0.6	4.0/0.016	1.72 1.62 1.68	15.3	0.252 0.322 0.337	.304	1.93 1.81 1.88	17.1
2	1.5/4.0	4.0/0.106	1.72 1.67 1.72	15.6	0.144 0.141 0.161	.149	1.78 1.82 1.79	16.4
3	2.9/0.6	7.7/0.016	5.49 5.44 5.64	50.4	0.053 0.060 0.053	.055	6.38 7.71 7.73	66.4
4	2.9/4.0	7.7/0.106	5.63 5.57 5.95	52.2	0.042 0.037 0.026	.035	5.99 5.62 6.34	54.6
5	2.9/11.0	7.7/0.291	6.00 * *	54.8	0.012 * *	--	6.17	--
6	4.1/0.6	10.8/0.016	11.90 12.0 13.6	114	0.019 0.017 0.013	.016	15.1 14.1 24.3	163
7	4.1/2.0	10.8/0.053	12.1 11.9 13.2	114	0.015 0.014 0.013	.014	13.6 12.2 13.7	120
8	4.1/4.0	10.8/0.106	12.3 12.0 13.3	114	0.0080 0.0094 0.0080	.0085	13.2 12.3 13.8	120

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial $(H/D)_i$: 1.0
Temperature (^oC): 19.8
Pressure (mm Hg): 734.4
Relative Humidity: 43%

$V_i^{1/3}$ (m) = 0.378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

*No significant gas levels were detected.

Experiment: B15830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.5/0.6	4.0/0.016	1.56 1.58 1.73	14.8	0.297 0.281 0.333	.304	1.84 1.83 1.86	16.8
2	1.5/2.0	4.0/0.053	1.57 1.59 1.73	14.9	0.223 0.194 0.163	.193	1.82 1.75 1.87	16.5
3	2.2/0.6	5.8/0.016	3.11 3.20 3.49	29.8	0.116 0.111 0.096	.108	3.87 3.97 3.83	35.5
4	2.2/4.0	5.8/0.106	3.12 3.23 3.37	29.6	0.091 0.079 0.056	.076	3.19 3.32 3.55	30.6
5	2.2/8.0	5.8/0.212	3.30 3.27 3.79	31.5	0.023 0.040 0.016	.026	3.48 3.39 4.43	34.4
6	3.5/0.6	9.25/0.016	8.66 7.71 8.46	75.6	0.022 0.031 0.027	.027	10.2 8.73 10.0	88.1
7	3.5/4.0	9.25/0.106	8.82 7.92 8.79	77.7	0.012 0.024 0.018	.018	9.40 8.00 9.11	80.7
8	3.5/8.0	9.25/0.212	9.21 8.24 9.24	81.3	0.007 0.012 0.004	.0074	9.36 8.54 9.39	83.1

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial $(H/D)_o$: 1.0
Temperature (°C): 21.5
Pressure (mm Hg): 734.8
Relative Humidity: 47%

$V_i^{1/3}$ (m) = 0.378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

Experiment: B16830

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.5/0.6	4.0/0.016	1.65 1.66 1.71	15.3	0.322 0.266 0.294	0.294	1.73 1.95 1.91	17.0
2	1.5/8.0	4.0/0.212	1.87 1.82 1.82	16.8	0.051 0.042 0.063	.052	1.95 2.17 1.86	18.2
3	2.2/0.6	5.8/0.016	3.30 3.28 3.19	29.7	0.120 0.14 0.11	.121	3.71 3.90 3.73	34.5
4	2.2/6.0	5.8/0.159	3.68 3.33 3.44	31.8	0.034 0.045 0.032	.037	3.79 3.41 3.71	33.2
5	2.2/11.0	5.8/0.291	3.89 * *	35.5	0.013 * *		4.03 * *	
6	3.5/0.6	9.25/0.016	8.54 8.77 8.72	79.2	0.024 0.019 0.016	.020	13.4 10.2 11.6	107.
7	3.5/6.0	9.25/0.159	8.52 9.46 8.72	81.3	0.016 0.0049 0.0070	.0092	8.63 9.77 8.83	82.9
8	3.5/11.0	9.25/0.291	* * *	--	--	--	--	--

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial $(H/D)_o$: 1.0
Temperature (°C): 21.6
Pressure (mm Hg): 735.8
Relative Humidity: 42%

$V_i^{1/3}$ (m) = 0.378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

*No significant gas levels were detected.

Experiment: 424844

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	2.65/.016	0.89 0.86 0.86	7.95	0.698 0.562 0.555	.605	1.01 0.90 1.09	9.13
2	1.0/2.0	2.65/.053	0.89 0.89 0.87	8.07	0.555 0.676 0.596	.609	0.99 1.03 0.91	8.92
3	1.8/0.6	4.76/.016	2.07 2.20 2.13	19.5	0.242 0.187 0.188	.206	2.27 2.38 2.62	22.1
4	1.8/2.0	4.76/.053	2.00 2.03 2.02	18.4	0.211 0.166 0.124	.167	2.06 2.07 2.13	19.1
5	1.8/6.0	4.76/.159	2.19 2.28 2.24	20.4	0.112 0.055 0.026	.065	2.22 2.43 2.32	21.2
6	2.4/0.6	6.35/.016	3.98 3.74 4.06	35.9	0.097 0.114 0.090	.100	5.01 4.49 4.81	43.6
7	2.4/2.0	6.35/.053	3.76 3.90 3.82	35.0	0.075 0.069 0.073	.072	4.50 4.33 4.30	40.0
8	2.4/6.0	6.35/.159	4.05 3.85 4.18	36.8	0.029 0.020 0.012	.020	4.52 4.14 4.26	39.3

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial $(H/D)_i$: 1.0
Temperature (^oC): 23.6
Pressure (mm Hg): 726.2
Relative Humidity: 44%

$V_i^{1/3}$ (m) = .378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

Experiment: 426840

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	2.65/.016	0.89 0.85 0.86	7.96	.589 .712 .711	.671	1.07 0.87 0.89	8.63
2	1.0/4.0	2.65/.106	0.92 0.92 0.88	8.29	.364 .375 .382	.374	0.93 1.04 0.89	8.72
3	1.8/0.6	4.76/.016	2.02 2.17 2.19	19.5	.194 .189 .222	.202	3.22 2.92 2.23	25.5
4	1.8/4.0	4.76/.106	2.03 2.05 2.00	18.5	.126 .099 .106	.110	2.05 2.11 2.11	19.1
5	1.8/8.0	4.76/.212	2.33 2.40 2.37	21.6	.021 .034 .057	.037	2.36 2.56 2.40	22.3
6	2.4/0.6	6.35/.016	3.68 3.52 3.66	33.1	.083 .109 .082	.091	4.42 4.29 5.07	42.0
7	2.4/4.0	6.35/.106	3.80 3.64 3.90	34.6	.054 .061 .062	.059	3.92 3.68 4.01	35.4
8	2.4/8.0	6.35/.212	4.03 3.87 4.04	36.4	.0034 .0074 .0043	.0050	NR 3.99 4.07	36.9

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial $(H/D)_o$: 1.0
Temperature (°C): 25.5
Pressure (mm Hg): 722.6
Relative Humidity: 54%

$V_i^{1/3}$ (m) = .378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

Experiment: 430840

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	2.65/.016	0.89 0.89 0.89	8.13	0.620 0.515 0.623	.586	1.08 1.11 0.91	9.44
2*	1.0/6.0	2.65/.159	0.96 0.93 0.96	8.68	0.285 0.148 0.203	.235	0.97 0.94 0.99	8.83
3	2.0/0.6	5.29/.016	2.63 2.81 2.68	24.7	0.169 0.148 0.152	.156	2.84 2.95 3.53	28.4
4	2.0/2.0	5.29/.053	2.70 2.50 2.66	23.9	0.138 0.131 0.118	.129	2.97 2.58 2.82	25.5
5	2.0/6.0	5.29/.159	2.82 2.98 2.85	26.4	0.037 0.044 0.050	.044	2.90 3.13 2.93	27.3
6	2.6/0.6	6.88/.016	4.31 4.34 4.72	40.7	0.075 0.095 0.081	.084	4.79 4.98 5.50	46.5
7	2.6/2.0	6.88/.053	4.13 4.31 4.48	39.3	0.078 0.075 0.052	.068	4.61 5.12 4.55	43.5
8	2.6/6.0	6.88/.159	4.47 4.46 4.84	41.9	0.020 0.028 0.018	.022	4.52 4.62 4.88	42.7

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial $(H/D)_i$: 1.0
Temperature (°C): 25.0
Pressure (mm Hg): 738.6
Relative Humidity: 45%

$V_i^{1/3}$ (m) = .378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

*Calibration subject to question.

Experiment: 501841

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	2.65/.016	.88 .87 .88	8.04	NR NR NR	--	NR NR NR	--
2	1.0/8.0	2.65/.212	.98 .99 1.03	9.14	.220 .0929 .137	.150	1.01 1.15 1.05	9.80
3	2.0/0.6	5.29/.016	2.73 2.84 2.92	25.9	.126 .124 .116	.120	3.49 3.51 3.58	32.2
4	2.0/4.0	5.29/.106	2.59 2.75 2.58	24.1	.100 .092 .099	.097	2.64 3.10 2.70	25.7
5	2.0/8.0	5.29/.212	2.98 3.02 3.05	27.6	.020 .027 .034	.027	3.15 3.07 3.26	28.9
6	2.6/0.6	6.88/.016	4.60 4.59 4.18	40.7	.062 .070 .077	.070	6.16 5.81 4.91	51.4
7	2.6/4.0	6.88/.106	4.48 4.42 4.37	40.4	.031 .045 .044	.042	4.57 4.63 4.44	41.6
8	2.6/8.0	6.88/.212	4.76 4.86 4.68	43.6	.012 .0079 NR	.010	4.81 5.21 NR	45.8

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial $(H/D)_i$: 1.0
Temperature (^oC): 26.5
Pressure (mm Hg): 732.5
Relative Humidity: 42%

$V_i^{1/3}$ (m) = .378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

Experiment: 507840

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1	1.0/0.6	2.65/.016	0.92 0.87 0.88	8.14	0.607 0.672 0.632	0.637	1.20 0.97 1.12	10.0
2*	1.0/0.6	2.65/.016	0.86 0.90 0.90	8.14	0.582 0.543 0.609	0.578	1.07 0.91 1.10	9.39
3*	2.0/0.6	5.29/.016	2.64 2.63 2.96	25.1	0.143 0.159 0.128	0.143	3.36 3.22 3.43	30.5
4*	2.0/0.6	5.29/.016	2.60 2.80 2.64	24.5	0.163 0.149 0.135	0.149	2.91 3.36 2.85	27.8
5	2.0/6.0	5.29/.159	2.80 2.81 3.04	26.4	0.056 0.034 0.064	0.051	2.87 3.00 3.08	27.3
6*	2.6/0.6	6.88/.016	4.28 4.60 4.29	40.2	0.094 0.084 0.087	0.088	5.99 5.66 5.47	52.2
7*	2.6/0.6	6.88/.016	4.14 4.50 4.47	40.0	0.090 0.077 0.077	0.082	5.08 5.52 5.20	48.2
8	2.6/6.0	6.88/.159	4.36 4.68 4.39	40.9	0.035 0.032 0.018	0.028	4.41 4.75 4.56	41.8

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial (H/D): 1.0
Temperature (°C): 21.1
Pressure (mm Hg): 733.8
Relative Humidity: 75%

$V_i^{1/3}$ (m) = .378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

*Filters removed from these sensors.

Experiment: 508840

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1*	1.0/0.6	2.65/.016	0.90 0.88 0.86	8.04	.607 .681 .644	0.644	1.05 0.91 1.09	9.32
2	1.0/0.6	2.65/.016	0.89 0.87 0.88	8.04	.654 .767 .657	0.693	1.17 0.88 1.14	9.7
3	2.0/0.6	5.29/.016	2.86 2.89 2.68	25.7	.126 .122 .155	0.134	3.47 3.69 3.39	32.1
4*	2.0/0.6	5.29/.016	2.64 2.68 2.73	24.5	.198 .172 .166	0.179	3.06 2.99 3.37	28.7
5*	2.0/6.0	5.29/.159	2.96 2.97 2.77	26.5	.063 .078 .087	0.076	3.31 3.02 2.89	28.1
6	2.6/0.6	6.88/.016	4.26 4.51 4.39	40.1	.084 .059 .085	0.076	5.72 4.62 5.52	48.3
7*	2.6/0.6	6.88/.016	4.08 4.08 4.31	40.0	.101 .084 .084	0.090	5.31 4.84 5.52	47.7
8*	2.6/6.0	6.88/.159	4.44 4.58 4.51	41.2	.0023 .0025 .0089	0.0046	4.47 4.79 4.57	42.1

Initial Volume (l): 54.1
Initial Relative Density: 4.19
Initial $(H/D)_i$: 1.0
Temperature (^oC): 22.1
Pressure (mm Hg): 739.1
Relative Humidity: 54%

$V_i^{1/3}$ (m) = .378

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.110

*Filters removed from these sensors.

Experiment: 706840

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1*	1.0/0.6	1.23/.0074	0.45 0.46	2.84	**	**		**
2	1.6/0.6	1.97/.0074	0.84 0.83	5.22	0.877 0.866	.872	1.04 0.90	6.1
3*	2.4/0.6	2.96/.0074	1.37 1.36	8.53	0.585 0.642	.614	1.87 1.91	11.8
4*	3.2/0.6	3.94/.0074	1.97 2.14	12.8	0.526 0.387	.457	3.83 3.53	23.0
5	4.05/0.6	4.99/.0074	3.20 3.45	20.8	0.299 0.223	.261	3.59 5.72	22.8
6*	4.7/0.6	5.79/.0074	4.41 4.10	26.6	0.182 0.176	.179	5.34 5.08	32.6
7*	5.5/0.6	6.77/.0074	5.75 5.76	36.0	0.187 0.142	.165	7.25 7.69	46.7
8*	6.4/0.6	7.88/.0074	7.41 7.70	47.2	0.116 0.123	.120	9.81 10.1	62.3

Initial Volume (l): 535
Initial Relative Density: 4.19
Initial $(H/D)_i$: 1.0
Temperature (^oC): 25.7
Pressure (mm Hg): 733.1
Relative Humidity: 64%

$V_i^{1/3}$ (m) = .812

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.161

*Filters removed from these sensors.
**Sensor saturated.

Experiment: 710840

Channel Number	Radius (m) / Height (cm)	$R/V_i^{1/3}$ / $H/V_i^{1/3}$	Time of Arrival TOA(s)	Avg. TOA/τ	Max. Obs. Mole Fraction PEAK	Avg. PEAK	Time of PEAK TOP(s)	Avg. TOP/τ
1*	1.0/1.3	1.23/.016	0.45 0.46	2.84	.989 .944	.962	0.68 0.81	4.66
2	1.6/1.3	1.97/.016	0.82 0.85	5.22	.944 .830	.887	0.89 0.87	5.50
3*	2.4/1.3	2.96/.016	1.44 1.31	8.60	.662 .610	.636	1.78 1.38	9.88
4*	3.2/1.3	3.94/.016	2.32 2.09	13.8	.390 .308	.349	2.57 2.50	15.9
5	4.05/1.3	4.99/.016	3.45 3.39	21.4	2.47 .198	.223	3.68 4.12	24.4
6*	4.7/1.3	5.79/.016	4.14 4.50	27.0	.152 .111	.132	4.65 5.01	30.2
7*	5.5/1.3	6.77/.016	5.46 6.05	36.3	.128 .104	.116	6.53 7.34	43.4
8*	6.4/1.3	7.88/.016	6.97 7.80	46.2	.089 .089	.089	8.48 9.32	55.6

Initial Volume (l): 535
Initial Relative Density: 4.19
Initial $(H/D)_i$: 1.0
Temperature (^{o}C): 28.0
Pressure (mm Hg): 735.1
Relative Humidity: 74%

$V_i^{1/3}$ (m) = .812

$\tau = \left[V_i^{1/3} / (g\Delta')_i\right]^{1/2}$ (s) = 0.161

*Filters removed from these sensors.

APPENDIX C

CALCULATION OF AVERAGE CLOUD CONCENTRATION

The result of the experimental program described in Section III was a large number of concentration time series at several locations for a particular release type (Appendix A). The most obvious parameters available from these traces were the time of arrival (TOA) of the cloud, the peak gas concentration, and the time when the peak occurred (TOP). However, in order to compare the data with predictions of a spatially averaged model (i.e. a box model), the data itself must be spatially averaged. Superimposed on the spatial average of the measured concentrations, a temporal average is necessary in order to try and eliminate such questions as sensor frequency response, concentration fluctuations due to the turbulence, and variability of the experiment. Large averaging times alleviate these problems, but too large an averaging time will unduly reduce the average concentration. Note that this is not true for determining the exposure ($\int_0^t y\,dt$) as a function of time. The 54.1 1 and $(H/D)_i = 1.0$ experiments were chosen to make vertical concentration measurements in order to determine an average concentration.

The first step in determining the "average" (in space and time) concentration from the data was to determine the time period over which the concentration time series for each sensor would be averaged. The following outline was used for a particular radius where concentration data were taken:

(1) t_1:= earliest TOA at the lowest sensor

(2) t_2:= latest TOP at the highest sensor

(3) $t_0 := (t_1 + t_2) / 2$

$\Delta t := (t_2 - t_1) / 2$

It should be noted that for t_3:= latest TOA at the highest sensor, $t_1 < t_3 < t_2$ always held. With t_0 and Δt defined, the concentration data for each sensor were averaged over a centered time interval ($2\Delta t$) about t_0 using

$$\overline{y}(r,z,t) = \frac{1}{2\Delta t} \int_{t_0-\Delta t}^{t_0+\Delta t} y(r,z,t)\, dt \tag{C-1}$$

This temporal average over the specified Δt was carried out for each sensor position in the cloud at the specified t_0. Note that the parameters t_0 and Δt were different for each cloud radius R.

Using these ideas, concentration as a function of height was summarized for each experiment, and the experiments were averaged for each run (a set of 2 or 3 experiments). From these numbers, two methods for determining an average concentration were pursued. A local cloud height H(r,t), defined as the height where the cloud concentration is zero, was determined by linear interpolation and extrapolation as follows:

(1) If the top sensor showed the presence of gas, H(r,t) was estimated by linear extrapolation between concentrations. Let $\overline{y}_i$ and z_i denote the concentration and height at the top sensor and $\overline{y}_{i-1}$ and z_{i-1} denote the same quantities for the next lowest sensor. Then

$$H(r,t) = z_i + \left[\frac{y_i}{\overline{y}_{i-1} - \overline{y}_i}\right] (z_i - z_{i-1}) \tag{C-2}$$

unless $\overline{y}_i > \overline{y}_{i-1}$ in which case

$$H(r,t) = z_i \tag{C-3}$$

(2) If the top sensor showed no gas present, the same procedure as above was used except that position i denotes the top sensor in the gas cloud. If the value of $H(r,t)$ exceeded the height of the lowest sensor not in the gas cloud $(i + 1)$, the local height was set to this position (i.e. $H(r,t) = z_{i+1}$).

(3) If only one sensor showed the presence of gas, the cloud height was estimated as the average height of the two lowest sensors. Or,

$$H(r,t) = (z_1 + z_2) / 2 \tag{C-4}$$

With the local cloud height known, the volume of the cloud was determined by

$$\pi R^2 H = 2\pi \int_0^R \int_0^{H(r,t)} r\,dz\,dr = 2\pi \int_0^R rH(r,t)\,dz \tag{C-5}$$

using the tradezoidal rule. Note that the time dependency on R and H is not explicitly noted. Appealing to the conservation of mass, the time-dependent averaged concentration is given by

$$\overline{y} = \frac{V_i}{\pi R^2 H} \tag{C-6}$$

where V_i denotes the initial cloud volume.

The second approach for estimating $\overline{y}$ is to estimate the integral

$$\pi R^2 H \overline{y} = 2\pi \int_0^R \int_0^{H(r,t)} \overline{y}(r,z,t)\,dz\,r\,dr \tag{C-7}$$

since $\int_0^{H(r,t)} \bar{y}(r,z,t)\,dz$ is easily estimated using the trapezoidal rule and the concentration data. First, however, $\bar{y}(r,0,t) = \bar{y}_0$ must be estimated. The following rules were used for each run:

(1) If the two lowest sensors showed the presence of gas, the ground level concentration was estimated by linear extrapolation. Or,

$$\bar{y}_0 = \bar{y}_1 + (\bar{y}_1 - \bar{y}_2)\left(\frac{z_1}{z_2 - z_1}\right) \qquad \text{(C-8)}$$

If $\bar{y}_0 > 1.1\ \bar{y}_1$, the $\bar{y}_0$ was set to $\bar{y}_1$.

(2) If only one sensor showed the presence of gas, $\bar{y}_0 = \bar{y}_1$.

Upon completion,

$$\bar{y} = \frac{\pi R^2 H \bar{y}}{\pi R^2 H} \qquad \text{(C-9)}$$

Of course, the quantity $\pi R^2 H \bar{y}$ should be conserved and therefore represents a measure of the accuracy of the data. The reported values are summarized below.

TABLE C-1

ESTIMATED AVERAGE CONCENTRATION FOR RELEASE OF PURE FREON-12, V_i = 54.1 l, and $(H/D)_i$ = 1.0

Time $(t_0 + \Delta t)$ (s)	Radius (m)	$\frac{\pi R^2 H \bar{y}}{\pi R^2 H}$	$\frac{V_i}{\pi R^2 H}$	$\frac{\lvert \pi R^2 H \bar{y} - V_i \rvert}{V_i}$
1.00	1.11	0.168	0.132	0.27
2.23	1.84	0.067	0.103	0.35
3.69	2.36	0.043	0.057	0.24
8.08	3.49	0.030	0.026	0.14

FILMED

0-8